(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 640 487 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **94113071.8**

(51) Int. Cl.[6]: **B41J 2/345**

(22) Date of filing: **22.08.94**

(30) Priority: **24.08.93 JP 209128/93**
07.09.93 JP 221682/93
07.09.93 JP 221683/93
05.10.93 JP 249242/93

(43) Date of publication of application:
01.03.95 Bulletin 95/09

(84) Designated Contracting States:
DE FR GB NL

(71) Applicant: **CASIO COMPUTER CO., LTD.**
6-1, Nishi-Shinjuku 2-chome
Shinjuku-ku,
Tokyo 163-02 (JP)

(72) Inventor: **Takeuchi, Eiichi, c/o Casio**
Computer Co., Ltd.
Patent Dep. Hamura R&D C.,
2-1, Sakae-cho 3-chome
Hamura-shi,
Tokyo 205 (JP)
Inventor: **Mizushina, Takahiro, c/o Casio**
Computer Co., Ltd.
Patent Dep. Hamura R&D C.,
2-1, Sakae-cho 3-chome
Hamura-shi,
Tokyo 205 (JP)

(74) Representative: **Patentanwälte Grünecker,**
Kinkeldey, Stockmair & Partner
Maximilianstrasse 58
D-80538 München (DE)

(54) Thermal dot printer.

(57) A thermal dot printer controls energy applied to individual heat generating members (101) to control the amount of heat generated by the heat generating members (101), thereby controlling the ink melting area on an ink ribbon, and transfers the melted ink on a paper to print a gradation image on the paper. The size Lm of each heat generating element (101) in the main scanning direction and the arranging pitch DOPm of the heat generating elements (101) in the main scanning direction have a relationship of Lm ≦ DOPm × (2/3), while the size Ls of each heat generating element (101) in the sub scanning direction has a relationship of Lm < Ls ≦ DOPs with respect to the pitch DOPs in the sub scanning direction and the size Lm of the heat generating elements (101) in the main scanning direction.

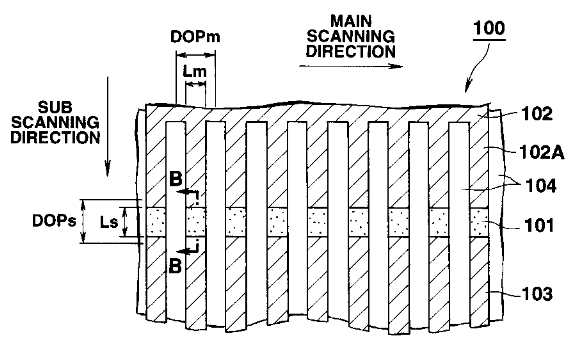


FIG.11A

EP 0 640 487 A2

The present invention relates to a thermal dot printer, and, more particularly, to a thermal dot printer which is capable of changing the sizes or areas of print dots to thereby control the gradation of a printed image.

A thermal dot printer selectively energizes numerous heat generating members, arranged on its head, in accordance with print data to color a thermosensible paper (sheet) or transfer ink on an ink ribbon on a sheet, thereby printing an image on the sheet.

Fig. 1 is an exemplary diagram for explaining a scheme of controlling the gradation (density) of an image that is to be printed by a thermal dot printer.

In Fig. 1, a circle D represent each pixel (the maximum inkable range) and a circle d indicates a dot that is actually printed (printed dot: portion that is inked). The size (or area) of the printed dot d increases as the gradation of a pixel becomes higher. This scheme of adjusting the size of printed dot d to change the gradation (density) of the pixel is called "area gradation method"

The size, Sm, of each pixel D in the main scanning direction (the lateral direction of the heat generating member) is approximately equal to the dot pitch, DOPm, in the main scanning direction, and the size, Ss, of the pixel D in the sub scanning direction (the feeding direction of paper) is equal to the dot pitch, DOPs, in the sub scanning direction.

The structure of a conventional thermal print head will now be explained with reference to Fig. 2A in which hatching is done to discriminate members, not to indicate the material of each member in cross section.

The thermal print head in Fig. 2 comprises a plurality of heat generating members 11 aligned in the main scanning direction, a common electrode 12 commonly connected to one ends of the heat generating members 11, and a plurality of segment electrodes 13 respectively connected to the other ends of the heat generating members 11. The size of the portion at which each heat generating member 11 is connected to the common electrode 12 and the size of the portion at which each heat generating member 11 is connected to the associated segment electrode 13 are equal to the size, Lm, of the heat generating member 11 in the main scanning direction. With the illustrated structure, when a voltage is applied to the segment electrodes 13 in accordance with print data, a current flows between the segment electrodes 13 and the common electrode 12 via the heat generating members 11, causing the heat generating members 11 to generate heat. This heat is transmitted to a printing medium, such as a thermosensible paper or an ink ribbon, to print an image.

Conventionally, the length Lm of the heat generating member 11 in the main scanning direction is nearly equal to the dot pitch DOPm in the main scanning direction, and the length Ls of the heat generating member 11 in the sub scanning direction is nearly equal to or larger than the dot pitch DOPs in the sub scanning direction.

Fig. 3 exemplarily illustrates how ink is transferred on a paper PA from an ink ribbon IR using a thermal print head, in a cross-sectional view. In Fig. 3, heat generating members 11 connected to unillustrated electrodes are provided on a head base plate 14 of the thermal print head. The paper PA is moved in contact with the ink ribbon IR on the heat generating members 11 in the sub scanning direction, and then the paper PA is fed upward as indicated by an arrow AA while the ink ribbon IR is discharged downward as indicated by an arrow BB.

The ink ribbon IR includes a base film BF and a layer of thermally meltable ink IN formed on the base film BF.

When the ink ribbon IR passes over the heat generating members 11, the heat transmitted via the base film BF from the heat generating members 11 melts the ink IN which is in turn transferred on the paper PA. The gradation of each pixel changes in accordance with the area of the transferred ink IN (the size of the printed dot d in Fig. 1). It is therefore possible to print an image with different gradations (densities) by controlling the amount of heat from the heat generating members 11.

There is another thermal print head which comprises a single heat generating member 21 extending in the main scanning direction, common electrodes 22 extending in the sub scanning direction and segment electrodes 23 also extending in the sub scanning direction, both electrodes 22 and 23 being alternately arranged in the main scanning direction and abutting on the heat generating member 21 as shown in Fig. 2B.

In the thermal print head in Fig. 2B, portions (heat generating portions) 25 of the heat generating member 21 between one segment electrode 23 and two adjoining common electrodes 22 generate heat.

As in the case of the heat generating member 11 in Fig. 2A, the length Lm of the heat generating portion 25 in the main scanning direction is nearly equal to the dot pitch DOPm in the main scanning direction, and the length Ls of the heat generating portion 25 in the sub scanning direction is nearly equal to or larger than the dot pitch DOPs in the sub scanning direction. The lengths of the portions of the common electrode 22 and the adjoining segment electrodes 23 facing each other with the heat generating portion 25 in between equals the width Ls of the heat generating portion 25.

According to the conventional thermal print head in Fig. 2A, the energy to be applied to the heat generating members 11 is controlled in stepwise manner to adjust the gradations of the individual pixels.

Figs. 4A to 4I exemplarily illustrate a change in the distribution of heat generated by the heat generating members 11 as the energy applied to the heat generating members 11 is altered in stepwise manner.

Fig. 4A shows the heat generating members 11 generating no heat. Figs. 4B to 4I illustrate how a heat distribution 15 changes when energies of different levels, from the level corresponding to the lowest gradation to the level corresponding to the highest gradation, are applied to the heat generating members 11. In Figs. 4B-4I, the heat distribution 15 is an exemplary distribution; for example, although the heat distribution 11 has not reached the top of the heat generating members 11, the heat has actually reached the top of the heat generating members 11. The heat distributions 15 in Figs. 4B and 4C indicate that a small amount of heat is transferred to the ink ribbon IR from the heat generating members 11 and the distribution of heat transmitted to the ink ribbon IR is not uniform. The non-uniform distribution is caused by a variation in the material of the heat generating members 11, a manufacturing variation in the heat generating members 11, etc. Figs. 4D to 4H illustrate that heat first spreads laterally and then moves toward the surface of the heat generating members 11. Fig. 4I shows the heat distribution 15 for the maximum applied energy.

Heat is transmitted to the ink ribbon IR from the heat generating members 11 in accordance with the heat distribution 15, and the ink IN melts to be transferred on the paper PA. There are two general modes in which the ink IN melts and is transferred on the paper PA from the ink ribbon IR.

When the heat energy applied to the ink ribbon IR is low, the ink IN in a middle portion of the ink layer melts and is separated therefrom (hereinafter referred to as "incomplete separation") and the ink IN with an insufficient thickness is transferred on the paper PA, as indicated by a solid line R1 in Fig. 5. When the heat energy is high, on the other hand, the ink IN in the whole ink layer melts and is separated from the whole ink layer or from the boundary between the ink layer and the base film BF (hereinafter referred to as "complete separation") and the ink IN with a full thickness is transferred on the paper PA, as indicated by a broken line R2.

Fig. 6 shows how ink IN is separated in accordance with the heat distributions shown in Figs. 4B to 4I. It is apparent from Fig. 6 that the applied energy of a low level separates the ink IN from the ink ribbon IR in the incomplete separation state, the applied energy of an intermediate level separates the ink IN from the ink ribbon IR with the mixture of the incomplete separation and complete separation, and the applied energy of a high level separates the ink IN from the ink ribbon IR in the complete separation state. In other words, as the applied energy becomes higher, the ink separation area increases, increasing the pixel gradation.

As described earlier with reference to Fig. 1, the density (gradation) of each pixel is expressed by the ink area, not by the density of ink. Therefore, ink itself should not have an uneven density and the ink should always have the maximum density. But, the density of the ink IN transferred in the incomplete separation state does not become the maximum value and varies.

The transferred ink IN in the incomplete separation state has a rough surface, whereas the transferred ink IN in the complete separation state has a flat surface. Depending on the surface state of the transferred ink IN, therefore, the quality of a printed image deteriorates. Accordingly, the conventional thermal print head, which causes complete ink separation and incomplete ink separation as described above referring to Fig. 6, cannot print an image of a high quality.

It is known that the relationship between the energy (electric energy) applied to the heat generating members 11 and the gradation of each pixel to be printed takes the form of a characteristic as shown in Fig. 7. As shown in Fig. 7, conventionally, the lowest value J(th) of the energy necessary to separate and transfer the ink IN is relatively large. As the heat diffusion in the heat accumulating member arranged around the heat generating members 11 is small, however, the applied energy J(m) for causing the maximum separation to provide the maximum gradation D(m) is relatively low. Accordingly, the changeable range of the applied energy is narrow, and the ratio of a change in gradation D(n) to a change in applied energy J(n) is large, so that a characteristic curve α has a relatively large slope.

To continuously change the densities of the individual pixels, the energy to be applied to the heat generating members 11 should be controlled by a small step, making the control of the applied energy difficult. Because of the large slope of the characteristic curve α, when the characteristic curve changes to a broken line $\alpha 1$ or $\alpha 2$ due to a variation in the resistance of the heat generating members, an environmental change, etc., or when the applied energy changes due to a variation in applied voltage, a variation in pulse width, etc., a change in the gradation of printed pixel, $\Delta D(n)$ becomes large. The gradation of a printed image therefore becomes unstable.

Human beings sense a change in gradation in a low-gradation region better than a change in gradation in a high-gradation region. To print a beautiful image, therefore, the gradation change in the low-gradation region should be expressed smoothly. Because of the reasons given above, however, it is difficult to smoothly express the gradation change in the low-gradation region.

As a solution to the above-described shortcoming, a thermal print head having a thermal concentration type heat generating members 31 having the shape as shown in Fig. 8 has been proposed. As the heat generating members 31 have a curved structure, however, their processing is difficult, the manufacturing cost is high and a variation in resistance becomes large.

According to the conventional thermal dot printer, paper is fed at the same pitch as the pitch of the dots of the thermal print head. The size of the printed dot d necessary to provide the maximum gradation (by which the paper is completely covered with the ink) is such that the oblique printed dots d contact one another, as shown in Fig. 9.

Given that the pitch of the heat generating elements of the thermal print head is P, the diameter of the maximum printed dot is $P \times \sqrt{2}$, as shown in Fig. 9.

Under the gradation control by the "area gradation method," as described above, the printed dots d have a constant gradation, and the gradation does not change even the printed dots d overlap one another. Therefore, the energy and ink are wasted for the portions where the printed dots d overlap one another.

The ratio of the wastefully consumed energy is computed as follows based on the area of the printed dot d. The area of the printed dot d having the maximum gradation is $\pi(P \times \sqrt{2/2})^2$. The shape of the printed dot which does not waste the applied energy is a square which has the pitch P as one side and has an area of P^2. The difference between those areas, $\pi(p \times \sqrt{2/2})^2 - p^2 = 0.57P^2$, corresponds to the wastefully consumed energy. That is, 57% of energy and ink are used wastefully.

The heat generating member 11 or heat generating portion 25 of the thermal print head having the structure as shown in Fig. 2A, 2B or 8 is easily heated by the heat from the adjoining heat generating members 11 or heat generating portions 25 and printed dots are easily linked. This may cause pixels aligned in the main scanning direction to be printed in a linked form so that the printed image has a stripe pattern as shown in Fig. 10, reducing the image quality.

As shown in Fig. 9, the up and down and right and left printed dots d are arranged at equal intervals of the pitch P while the oblique printed dots have an interval of $P \times \sqrt{2}$. In general, the color of a colored printed image is determined by the mixing of the colors of a plurality of printed dots. When the intervals (center distances) between the printed dots are not constant as shown in Fig. 9, however, the color mixing ratio varies depending on the positions of the printed dots, making it difficult to obtain the combined color that is close to the desired color.

It is therefore a primary object of the present invention to provide an inexpensive thermal dot printer which prints a gradation image with a high quality by changing the size of the printed dots.

It is another object of this invention to provide an inexpensive thermal dot printer which prints an image with a high quality.

It is a further object of this invention to provide an inexpensive thermal dot printer which prints an image with a high energy efficiency and high color reproducibility.

To achieve the above objects, a thermal dot printer according to the first aspect of this invention comprises:

a plurality of heat generating elements aligned in a main scanning direction;

feeding means for moving a print medium in a sub scanning direction in relative to the heat generating elements; and

control means, connected to the heat generating elements, for variably controlling energy to be applied to the heat generating elements to change areas of printed dots of the print medium, thereby forming a gradation image, and controlling the feeding means to feed the print medium,

a size Lm of each of the heat generating elements in the main scanning direction and an arranging pitch DOPm of the heat generating elements in the main scanning direction having a relationship of $Lm \leqq DOPm \times (2/3)$, a size Ls of each of the heat generating elements in the sub scanning direction having a relationship of $Ls \leqq DOPs$ a pitch DOPs, determined by an amount of relative movement of the print medium by the feeding means and a printing timing.

It is desirable that the size Ls of the heat generating elements in the sub scanning direction be greater than the size Lm in the main scanning direction.

With the heat generating elements constituted to satisfy the above condition, an image with an excellent quality can be printed as indicated by the specific example given in Fig. 18.

A thermal dot printer according to the second aspect of this invention comprises:

a thermal print head including a plurality of heat generating elements aligned in a main scanning direction, and electrodes, connected to both ends of the heat generating elements in a sub scanning direction, for supplying a current to the heat generating elements to generate heat therefrom; and control means, connected to the electrodes, for variably controlling energy to be applied to the heat generating elements to change areas of printed dots of a print medium, thereby forming a gradation image,

a width T of connecting portions of the heat generating elements and the electrodes and a size Lm of the heat generating elements in the main scanning direction having a relationship of $T \leqq Lm \times (2/3)$.

With the connecting portions of the heat generating elements and electrodes constituted to satisfy the above condition, this thermal dot printer, like the one according to the first aspect, can print an image with an excellent quality.

A thermal dot printer according to the third aspect of this invention comprises:

a thermal print head including a plurality of heat generating elements aligned in a main scanning direction;

control means for energizing the heat generating elements to generate heat therefrom, thereby forming a dot image on a print medium; and

feeding means for feeding the thermal print head and the print medium in relative to each other every time one print in the main scanning direction is completed, the feeding means including feeding control means for performing control so as to set an amount of relative movement of the thermal print head and the print medium to $P/\sqrt{3}$ where P is an arranging pitch of the heat generating elements in the main scanning direction,

the control means energizing odd-numbered heat generating elements of the thermal print head on an N-th line in the sub scanning direction and energizing even-numbered heat generating elements on an $(N+1)$-th line in sub scanning direction.

With the above structure, the overlapping of printed dots of the maximum gradation becomes smaller as compared with the prior art. As exemplified in Fig. 22B, the distances between the centers of the individual printed dots become constant, thus improving the quality of an image printed in color.

According to the first to third thermal dot printers, the print medium may comprise an ink tape having, for example, yellow, magenta and cyan ink regions, and a sheet on which ink on the ink tape is transferred to form a gradation image, and the control means may repeat printing with each of the three inks three times to print a full-colored image.

To control the amount of heat from the heat generating elements, the control means may control the time for energizing the heat generating elements. The energization time may be controlled by controlling the number of pulses applied to the heat generating elements.

It is desirable that the ink ribbon used as the print medium may have a base film whose thickness is 5 μm or smaller.

The heat generating elements may be designed to have substantially a convex shape to provide an image with higher quality.

This invention can be more fully understood from the following detailed when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagram for explaining pixels, their gradation, a dot pitch in a main scanning direction and a dot pitch in a sub scanning direction;

Figs. 2A and 2B are diagrams exemplifying the structure of heat generating members of a conventional print head;

Fig. 3 is a cross-sectional view exemplarily showing how printing is done on a sheet from an ink ribbon by thermal transfer;

Figs. 4A through 4I are diagrams showing the relationships between applied energy and heat distributions;

Fig. 5 is a diagram for explaining how ink is separated from a base film;

Fig. 6 is a diagram for explaining the relationship between applied energy and the separation of ink;

Fig. 7 is a characteristic curve showing the relationship between applied energy and gradation;

Fig. 8 is a diagram showing an another example of the structure of the heat generating members of the conventional print head;

Fig. 9 is a diagram for explaining the distance between printed dots;

Fig. 10 is a diagram for explaining the state in which printed dots aligned in the main scanning direction are mutually linked;

Fig. 11A is a plan view showing the structures of heat generating members and electrodes of a thermal print head according to a first embodiment;

Fig. 11B is a cross-sectional view of the thermal print head taken along the line B-B in Fig. 11A;

Figs. 12A through 12H are diagrams illustrating how heat energy generated from the heat generating members propagate;

Fig. 13 is a diagram showing separation states of ink in accordance with a change in heat energy generated from the heat generating members;

Fig. 14 is a characteristic curve showing the relationship between applied energy and dot gradation;

Fig. 15 is a plan view showing the structure of a print head according to a second embodiment;

Fig. 16 is a perspective view showing a modification of the thermal print head according to the first embodiment;

Fig. 17 is a perspective view showing a modification of the thermal print head according to the second embodiment;

Fig. 18 is a diagram illustrating the relationship among the size of the heat generating members in the main scanning direction, the size thereof in the sub scanning direction and print results;

Fig. 19A is a plan view showing the structure of a thermal print head according to a third embodiment;

Fig. 19B is a cross-sectional view of the thermal print head taken along the line B-B in Fig. 19A;

Fig. 20A is a diagram for explaining the distribution of the heat generated from the heat generating members in the horizontal direction;

Fig. 20B is a diagram for explaining the distribution of the heat generated from the heat generating members in the vertical direction;

Fig. 21 is a diagram showing separation states of ink in accordance with a change in heat energy generated from the heat generating members;

Fig. 22A is a diagram showing a dot alignment according to a fourth embodiment of this invention;

Fig. 22B is a diagram for explaining the distance between dots shown in Fig. 22A;

Figs. 23A and 23B are diagrams showing the thickness of the base film of an ink ribbon and how heat is diffused in the base film;

Fig. 24 is a block diagram of a thermal dot printer embodying the present invention;

Fig. 25 is a schematic structural diagram of essential portions of the thermal dot printer around a print head;

Fig. 26 shows the structures of the essential portions of the printing section of the thermal dot printer;

Fig. 27 is a table for explaining the structure of a gradation data controller;

Fig. 28 is a circuit block diagram showing the print head, a head driver and a serial/parallel converter;

Figs. 29A through 29G are timing charts for explaining the printing operation of the thermal dot printer;

Fig. 30 is a diagram for explaining the structure of an ink ribbon for color printing; and

Fig. 31 is a flowchart for explaining the printing operation for making full-colored printing.

Preferred embodiments of the present invention will now be described referring to the accompanying drawings.

First Embodiment

Fig. 11A shows the structure of a thermal print head according to a first embodiment, and Fig. 11B is a cross-sectional view taken along the line B-B in Fig. 11A.

As illustrated, a thermal print head 100 of this embodiment comprises a head base plate 104, heat generating members 101 aligned on the head base plate 104 in the main scanning direction, a common electrode 102 commonly connected to the heat generating members 101 via connecting portions 102A, segment electrodes 103 connected the respective heat generating members 101, and a heat accumulating member 105 located on the head base plate 104 and surrounding the heat generating members 101. A support member is provided between the heat generating members 101 and the head base plate 104 as needed.

The size Lm of the heat generating members 101 in the main scanning direction is set 2/3 of the dot pitch DOPm in the main scanning direction. The size Ls of the heat generating members 101 in the sub scanning direction is also set 2/3 of the dot pitch DOPs in the sub scanning direction.

Both ends of the heat generating member 101 in the sub scanning direction are respectively connected to the connecting portion 102A of the common electrode 102 having the same width as the width Lm of the heat generating member 101 and the associated segment electrode 103. A voltage is selectively applied between the common electrode 102 and the segment electrodes 103 in accordance with print data by a head driver which will be described later. In accordance with the applied voltage or the voltage applying time, the heat generating members 101 generate heat and transmit the heat energy to an ink ribbon.

Figs. 12A through 12H are diagrams exemplarily showing the distribution, HD, of heat generated by the thermal print head 100.

Fig. 12A shows that the heat generating members 101 are generating no heat with the print gradation (density, gray scale) of 0 and the energy of 0 applied to the heat generating members 101. Figs. 12B to 12H show the distributions of heat generated by the heat generating members 101 when the applied energy is changed in seven stages to change the print gradation from the lowest level to the highest level.

Figs. 12B and 12C show that with low applied energy, the spreading of heat in the horizontal direction is smaller than the dot pitch DOPm in the main scanning direction (thus the pixel size D), although the heat distribution HD in the heat generating members 101 is not uniform.

Figs. 12D and 12E show that the generated heat propagates to the surface portion of the heat generating member 101 at the stage in which the applied energy to the heat generating member 101 is relatively small.

Figs. 12F through 12H show that the generated heat propagates via the heat accumulating member 105 located adjacent to each heat generating member 101 on the base plate 104 when the applied energy to the heat generating members 101 increases.

Fig. 13 exemplarily shows the areas and thicknesses of ink IN that is separated from an ink ribbon IR in association with the heat distributions HD shown in Figs. 12B to 12H. At the stage where the heat energy is small (Figs. 12B and 12C), the ink IN is incompletely separated and transferred a paper PA as shown in Fig. 13. This incomplete separation however occurs only in a narrow range in accordance with the size Lm of the heat generating members 101 in the main scanning direction. At the stage where the applied energy to the heat generating member 101 is relatively small, the generated heat propagates to the surface portion of the heat generating member 101. At the stage where the applied energy is relatively small, therefore, the incomplete separation of the ink In occurs, after which as the applied energy increases, the area of the complete separation sequentially increases to the maximum value (maximum gradation).

Fig. 14 shows the relationship between energy applied to the heat generating members and dot gradation (print density). As described above, the sizes Lm and Ls of the heat generating members 101 in the main scanning direction and the sub scanning direction are respectively smaller than the dot pitches DOPm and DOPs in the main scanning direction and the sub scanning direction. That is, the area that contributes to generating heat is smaller than that of the prior art. When the same energy is applied to the heat generating members of this embodiment and to the heat generating members of the prior art, therefore, the heat generating members of this embodiment concentrically generate more heat. The heat generated by the heat generating members 101 of this embodiment is therefore concentrically applied to the ink IN in a narrow range of the ink ribbon IR. Therefore, the effective heat energy for starting the separation of the ink IN at the stage where the applied energy to the heat generating member 101 is relatively small. The lowest applied energy J(th) thus becomes smaller than the one in the prior art (see Fig. 7). The heat energy for causing the maximum separation propagates to the ink ribbon IR via the heat accumulating member 105 having a relatively large specific heat located around the heat generating members 101. As the heat generating members 101 become smaller than those of the prior art, the area of the heat accumulating member 105 around the members 101 become larger. Thus, the maximum applied energy J(m) for the maximum separation becomes greater than that in the prior art. According to the thermal print head 100 of this embodiment, therefore, the range in which the applied energy can change from the lowest level J(th) to the maximum level J(m) becomes wider than that in the prior art. Accordingly, the slope of the characteristic curve α showing a change in gradation D(n) with respect to the applied energy J(n) becomes smaller than that in the prior art. It is therefore possible to provide a large unit change in applied energy to obtain an arbitrary gradation, thus facilitating the gradation control.

As the slope of the characteristic curve a is small, a variation in gradation, $\Delta D(n)$, is small even when the characteristic curve changes to the broken line $\alpha 1$ or $\alpha 2$ or even when the applied energy changes due to a variation in the resistance of the heat generating members, an environmental change, etc. This permits pixels with an arbitrary gradation to be printed stably.

When the energy close to the lowest applied energy J(th) is applied to the heat generating members 101, the generated heat propagates only within the range close to the heat generating members 101. The plane area of the heat generating members 101 is approximately 4/9 of that of the conventional heat generating members. Even part of the ink IN is separated with a low applied energy due to the uneven heat distribution, the layer of the separated ink is very thin and has a small area, so that the influence of the separated ink on the quality of the printed image is very small.

According to the thermal dot printer of this embodiment, the incomplete separation is switched to the complete separation at the stage where the applied energy is relatively small. It is therefore possible to smoothly change the densities of printed dots in a low-gradation region and keep the density of transferred ink nearly constant. This can provide a beautiful image with high quality.

Second Embodiment

Fig. 15 shows the planar structure of a print head according to a second embodiment. This thermal print head 110 comprises a single heat generating member 111 extending the main scanning direction, common electrodes 112, segment electrodes 113, and a head base plate 114 for supporting the member 111 and the electrodes 112 and 113. The common electrodes 112 and segment electrodes 113 both abut on the heat generating member 111 and are arranged alternately in the main scanning direction. Portions of the heat generating member 111 which are located between one segment electrode 113 and the adjoining two common electrodes 112 are heat generating portions 115 which generate heat. In accordance with the voltage applied between the common electrodes 112 and the segment electrode 113, a current flows via the heat generating portions 115 to the adjoining two common electrodes 112 from the segment electrode 113, causing the heat generating portions 115 to generate heat.

The size Lm of the heat generating portion 115 in the main scanning direction and the size Ls there of in the sub scanning direction are the same as those of the heat generating members 101 shown in Fig. 11 and are respectively 2/3 of the dot pitches DOPm and DOPs. As the portions of the heat generating member 111 which abut the common electrodes 112 do not generate heat, the size Lm is defined to be Lm = DOPm - W (where W is the width of the common electrode 112). The width W of the common electrode 112 should be so determined as to set $Lm \fallingdotseq (2/3) \times DOPm$.

With this structure, the sizes Lm and Ls of the heat generating portions 115 in the main scanning direction and sub scanning direction are smaller than the dot pitches DOPm and DOPs in those directions, thus providing characteristics nearly equal to the heat distribution characteristics shown in Figs. 12A-12H, the separation characteristic of ink IN shown in Fig. 13 and the applied energy v.s. print gradation characteristic shown in Fig. 14. It is therefore possible to print a high-quality image as per the first embodiment.

Modifications

Although the heat generating member of the thermal print heads according to the first and second embodiments is located on the flat base plate, the heat generating members 101, common electrode 102 and segment electrodes 103 may be provided on a glaze 109 having a convex shape, as shown in a perspective view of Fig. 16. In this case, the entire protruding portion around the heat generating members 101 is covered with an overcoat (protective layer) 108 to protect the heat generating members 101, etc. against the friction with paper at the time of printing.

Likewise, the heat generating member 111 in the second embodiment may be formed to have a convex shape, or the common electrodes 112 and segment electrodes 113 may be provided on a glaze having a convex shape with the heat generating member 111 placed on the electrodes 112 and 113, as shown in Fig. 17.

With this structure, the heat generating member 101 or 111 surely contacts the ink ribbon IR so that the heat generated by the heat generating member is transmitted to the ink ribbon IR without waste. Since the sizes of the heat generating member 101 and the heat generating portion 115 are the same as those of the first and second embodiments, a high-quality image can be printed as described above.

Study on Size of Heat Generating Element

A detailed consideration will now be given of the size of the heat generating elements (heat generating member 101 and heat generating portion 115). Fig. 18 is a diagram illustrating the relationship among the sizes Lm and Ls of the heat generating members 101 in the main scanning direction and the sub scanning direction and print results. This relationship was obtained by an experiment.

Fig. 18 shows the dot pitch DOPm in the main scanning direction, the dot pitch DOPs in the sub scanning direction, the size Lm of the heat generating members in the main scanning direction, the size Ls thereof in the sub scanning direction, and print results, row by row. The unit of the dot pitches and the sizes of the heat generating members are given by μm. As the print result, the mark X indicates a poor image quality, the triangle mark indicates acceptable low-quality printing, and the double circle indicates an image with an excellent quality. The print pitches indicate the dot pitches DOPm and DOPs in the main and sub scanning directions.

No. 1 to No. 8 in Fig. 18 are the cases where the dot pitches DOPm and DOPs in the main and sub scanning directions are both set to 139 μm suitable for hard copy or the like of TV images. As shown in No. 1 to No. 5, with the size Ls of the heat generating members in the sub scanning direction kept at 139 μm equal to the dot pitch DOPs in the sub scanning direction, as the size Lm of the heat generating members in the main scanning direction is sequentially decreased from 139 μm equal to the dot pitch DOPm in the main scanning direction, to 120 μm, to 100 μm, to 90 μm and then to 80 μm, the print result changes from the mark X, to the triangle mark and then to the double circle mark. It is found that when the size Lm of the heat generating members in the main scanning direction is equal to or smaller than 90 μm or around 2/3 of the dot pitch DOPm (= 139 μm) in the main scanning direction, in particular, good print results are obtained.

When the size Ls of the heat generating members in the sub scanning direction is set smaller (90 μm) than the dot pitch DOPs (= 139 μm) in the sub scanning direction as shown in No. 6, a better print result is obtained, though the distinction is not apparent from the same double circle mark. Even if the size Ls of the heat generating members in the sub scanning direction is set smaller than the dot pitch DOPs in the sub scanning direction as shown in No. 7 and No. 8, the print result is poor (mark X) when the size Ls (120 μm, 80 μm) of the heat generating members in the sub scanning direction is set smaller than the size Lm (139 µm, 90 µm) in the main scanning direction.

No. 9 to No. 16 are the cases where the dot pitches DOPm and DOPs in the main and sub scanning directions are both set to 125 µm widely used for a facsimile or the like. The same results as discussed above are also obtained in those cases.

As shown in No. 9 to No. 13, with the size Ls of the heat generating members in the sub scanning direction kept at 125 µm equal to the dot pitch DOPs in the sub scanning direction, as the size Lm of the heat generating members in the main scanning direction is sequentially decreased from 125 µm equal to the dot pitch DOPm in the main scanning direction, to 100 µm, to 90 µm, to 80 µm and then to 70 µm, the print result changes from the mark X, to the triangle mark and then to the double circle mark. In this case too, when the size Lm of the heat generating members in the main scanning direction becomes smaller than 80 µm or around 2/3 of the dot pitch DOPm (= 125 µm) in the main scanning direction, in particular, very good print results are obtained. When the size Ls of the heat generating members in the sub scanning direction is set smaller than the dot pitch DOPs (= 139 µm) in the sub scanning direction as shown in No. 14, a better print result is obtained. Even if the size Ls of the heat generating members in the sub scanning direction is set smaller than the dot pitch DOPs in the sub scanning direction as shown in No. 15 and No. 16, the print result is poor as indicated by the mark X when the size Ls of the heat generating members in the sub scanning direction is set smaller (120 pm, 90 µm) than the size Lm (125 µm, 100 µm) in the main scanning direction.

In short, it is apparent from the above that the sizes Lm and Ls of the heat generating members in the main and sub scanning directions and the dot pitches DOPm and DOPs in the main and sub scanning directions have relationships $DOPm \times (2/3) \geqq Lm$ and $DOPs \geqq Ls > Lm$.

The above is the ground of setting the sizes of the heat generating elements (heat generating members 101 and heat generating portions 115) in the first and second embodiments to 2/3 of the dot pitches.

Third Embodiment

Although the sizes of the heat generating members and heat generating elements are set smaller than the dot pitches in the above-described embodiments, the heat generating members or the heat generating portions may take an arbitrary size if the size of the portions which substantially generate heat.

In this respect, an embodiment in which a thermal print head using heat generating members whose sizes are substantially the same as the dot pitches will be described below.

Fig. 19A is a plan view showing the structure of a thermal print head according to a third embodiment, and Fig. 19B is a cross-sectional view taken along the line B-B in Fig. 19A.

As illustrated, a thermal print head 120 comprises a head base plate 124, heat generating members 121 aligned on the head base plate 124 in the main scanning direction, a common electrode 122 commonly connected to the heat generating members 121 via connecting portions 122A, segment electrodes 123 connected the respective heat generating members 121, and a heat accumulating member 125, which covers all those elements and serves as a protective layer. A support member is provided between the heat generating members 121 and the head base plate 124 as needed.

The total number of the heat generating members 121 is the same as the number of maximum pieces of data (dots) of an image for one main scanning line and the aligning pitch of the heat generating members 121 is the dot pitch P.

The size Lm of the heat generating members 121 in the main scanning direction is set slightly smaller (95 to 75%) than the dot pitch P. The size Ls in the sub scanning direction is equal to the dot pitch P.

The heat generating member 101 in the sub scanning direction is connected at one end to the connecting portion 122A of the common electrode 122 and is connected at the other end to the associated segment electrode 123. The common electrode 122 is applied with, for example, a ground voltage.

The sizes of connecting portions 122A of the common electrode 122 and the segment electrodes 123 are nearly 2/3 of the size Lm of the heat generating members 121 in the main scanning direction. Therefore, the size of the connecting portions 122A of the common electrode 122 with respect to the heat generating members and the size of the connecting portions between the heat generating members 121 and the segment electrodes 123 are also approximately 2/3 of the size Lm.

The distribution of heat generated by the heat generating members 121 will now be discussed with reference to Figs. 20A and 20B.

Fig. 20A shows the heat generating member 121 turned 90 degrees and shows the distribution of the heat generated from the heat generating member 121 (horizontal spreading of heat) when the energy to be applied to the heat generating member 121 is changed to seven levels of HD1 to HD7 in accordance with the dot gradation from the lowest gradation to the highest gradation. Fig. 20B shows the heat distribution in the vertical direction when the applied energy to the heat generating member 121 is changed in a similar manner.

Since the width of the connecting portion 122A of the common electrode 122 and the width of the segment electrode 123 are set to 23 of the size of the heat generating member 121, the current path is located in the center portion of the heat generating member 121. The heat generation is therefore concentrated on the center portion of the heat generating member 121. At the stage of low applied energy, therefore, the center portion of the heat generating member 121 is concentrically heated as indicated by the heat distribution HD1 and the heat propagates from the center portion to the peripheral portion, drawing substantially a concentric circle, as indicated by the heat distributions HD2 to HD7 as the applied energy increases.

The heat distribution HD1 in Fig. 20B indicates that the unevenness of the heat distribution is small at the stage where the applied energy to the heat generating member 121 is low. The heat distribution HD2 shows that due to the concentrated heat generation at the center portion of the heat generating member 121, the heat propagates to the surface portion of the heat generating member 121 at the stage where the applied energy is low. The heat distributions HD3 to HD7 show that as the applied energy increases, the heat propagates through the heat accumulating member 125.

Fig. 21 shows states of separating ink when heat energies of the heat distributions HD1 to HD7 in Figs. 20A and 20B are applied to the ink ribbon IR.

As shown in Fig. 21, at the stage where the amount of heat generated by the heat generating member 121 is small (HD1, HD2), the ink IN is transferred on a paper PA from the ink ribbon IR in an incomplete separation state but in a narrow range. Heat generation concentrically occurs at the center portion of the heat generating member 121 and the generated heat reaches the surface portion quickly, so that the ink IN becomes a complete separation state at the low-gradation stage (HD3). Thereafter, as the applied energy increases, the area of the complete separation gradually increases to the maximum gradation (maximum area) (HD4 to HD7).

Since the heat generating member 121 generates heat at the center portion, the minimum applied energy J(th) required to separate the ink IN is relatively small. To ensure the maximum separation, the entire heat generating member 121 should be heated. Because the widths of the electrodes 122 and 123 are narrow for the peripheral portion of the heat generating member 121, the current path is not formed there. Therefore, a small amount of heat is generated at the peripheral portion of the heat generating member 121. Accordingly, the heat generated at the center portion of the heat generating member 121 propagates to heat the whole heat generating member 121, causing the maximum ink separation. The maximum applied energy J(m) needed for the maximum ink separation thus becomes relatively large. This increases the range in which the applied energy changes from the minimum (lowest) applied energy J(th) to the maximum (highest) applied energy J(m) and reduces the slope of the characteristic curve α of the gradation D(n) with respect to the applied energy J(n).

The relationship between the applied energy and print gradation thus becomes in similar to the characteristic of the thermal print head of the first embodiment, as shown in Fig. 14.

The range of the applied energy for the thermal print head of this embodiment is large as in the first and second embodiments, it is possible to set a large step of a change (unit change) in applied energy to obtain an arbitrary dot gradation. This facilitates the gradation control.

Since the slope of the characteristic curve α is small, even if the characteristic of the heat generating member or the applied energy varies, a variation in the gradation of printed pixels, ΔD(n), is small. This stabilizes the gradation and facilitates the compensation for the gradation.

The variation in the distribution of heat generated with around the lowest applied energy J(th) is smaller than that of the heat generating members 11 of the prior art. Further, this variation occurs only at the stage where the printed pixels have a low gradation, and does not substantially affect the quality of a printed image.

Since the ink IN is separated from the base film BF in a complete separation state at the low-gradation stage, a gradation change in a low-gradation region can be expressed finely Further, the density of transferred ink itself is nearly constant, so that a beautiful image can be printed.

As long as the sizes of the connecting portions between the electrodes 122 and 123 and the heat generating member 121 satisfy the above-described conditions, the other portions of the electrodes 122 and 123 can have arbitrary sizes (widths) and may be set wider to reduce the resistance.

The heat generating member 121 may be designed to have a convex shape as shown in Figs. 16 and 17, or may take another arbitrary structure as long as the size in the main scanning direction of the portion which substantially generates heat is set equal to or smaller than 2/3 of the dot pitch in the main scanning direction (aligning pitch of the heat generating members).

Fourth Embodiment

Referring now to Figs. 22A and 22B, the structure of a thermal dot printer which has an excellent color reproducibility and can save consumed power and ink will be described.

In this embodiment, the dot pitch in the sub scanning direction is set to $1/\sqrt{3}$ of the dot pitch in the main scanning direction.

This embodiment performs heat generation control in such a manner that for an odd-numbered scanning line, only odd-numbered heat generating members generate heat in accordance with the print gradation and even-numbered heat generating members do no generate heat, whereas for an even-numbered scanning line, only even-numbered heat generating members generate heat in accordance with the print gradation and odd-numbered heat generating members do no generate heat. Accordingly, only odd-numbered printed dots Dodd are colored for an odd-numbered scanning line, and only even-numbered printed dots Deven are colored for an even-numbered scanning line, as shown in Fig. 22A.

With this dot arrangement, the distances between the centers of adjoining three printed dots are all set to "$2P/\sqrt{3}$" as shown in Fig. 22B. In the dot arrangement shown in Fig. 22A, therefore, the distances between the center of any printed dot and the centers of adjoining six printed dots are all equal to one another ($2P/\sqrt{3}$).

By respectively printing pixels in, for example, three colors of yellow, magenta and cyan in their areas corresponding to associated gradation data by means of transfer, sublimation, coloring or the like, the colors of the individual dots are properly combined to ensure excellent color reproducibility.

Provided that the arranging pitch of the heat generating members in the main scanning direction is P, the printed dots needed to obtain the maximum gradation become circles with a radius of $2P/\sqrt{3}$. In this case, the area of the ink-overlapping portion or the area of the overlapping portion of the circles in Fig. 22A can be obtained from the equation $\pi(P \times 2/3)^2 - P^2$ whose solution is $0.396P^2$.

The dot arrangement shown in Fig. 22A can save energy and ink by 18% more than the dot arrangement shown in Fig. 9, and can greatly contribute to reducing the cost.

According to the above arrangement of printed dots, the number of printed dots per single image is obtained from $\{(X/P)/2\} \times \{Y/(P/\sqrt{3})\}$ where X is the printing size in the main scanning direction and Y is the printing size in the sub scanning direction. According to the prior art shown in Fig. 9, the number of printed dots per single image is obtained from $(X/P) \times (Y/P)$. Therefore, the number of printed dots per single image in this embodiment is 0.86 times the number of printed dots per single image according to the prior art. This means that this embodiment merely needs 86% of the memory capacity for image data required by the prior art.

As a certain inactive period is given to each dot, the influence of the thermal hysteresis of the heat generating members is reduced, thus facilitating the gradation control. If the control threshold value of the thermal hysteresis is set to the same value as used in the prior art, the control threshold value of the thermal hysteresis comes earlier by the quickened cooling originated from the inactive state, thus allowing the heat generating members to start the next printing earlier accordingly. This can shorten the paper feeding period T_M and increase the printing speed.

According to this embodiment, as described above, a color image can be printed with excellent reproducibility and consumed power and ink can be saved. Further, the memory capacity for storing image data can be reduced.

Although odd-numbered dots are printed in an odd-numbered scanning line and even-numbered dots are printed in an even-numbered scanning line in this embodiment, even-numbered dots may be printed in an odd-numbered scanning line and odd-numbered dots may be printed in an even-numbered scanning line.

About Ink Ribbon

The ink ribbon IR used in the first to fourth embodiments will now be considered.

When the base film BF of the ink ribbon IR is thick, the heat energy generated by the heat generating members spreads in the base film BF as exemplarily shown in Fig. 23A. This makes the concentration of heat energy, generated by the heat generating members, on a point of the ink IN difficult and would thus likely to cause incomplete separation, resulting in unstable gradation.

Through the experiment conducted by the present is, when the thickness of the base film BF is equal to or greater than 6 µm, incomplete separation of ink IN is likely to occur and the gradation becomes unstable whereas when the thickness of the base film BF is equal to or less than 5 µm, complete separation of ink IN is likely to occur, thus stabilizing the gradation.

It is therefore desirable that the thickness of the base film BF of the ink ribbon IR in the first to fourth embodiments be equal to or less than 5 µm. Accordingly, the complete separation of ink occurs and the area of the separated ink precisely matches with the dot gradation specified by image data, so that an image with a considerably high quality can be printed.

Fifth Embodiment

The general structure and the operation of the thermal dot printer whose characterizing structure has been discussed in the foregoing description of the first to fourth embodiments will now be described with reference to Figs. 24 to 30.

Fig. 24 is a block diagram showing the circuit structure of the thermal dot printer. In Fig. 24, an image data output unit 201 is a circuit which temporarily stores image data and outputs, for example, 7-bit image data SD whose printing gradation is specified pixel by pixel to a gradation data controller 203.

The gradation data controller 203 performs predetermined compensation on gradation data included in the image data SD, sent from the image data output unit 201, based on a preprogrammed gradation architecture, such as the applied energy v.s. gradation characteristic shown in Fig. 14, and outputs the compensated image data as serial print data S_4 to a serial/parallel converter 207. A control pulse generator 205, which performs the general control of the thermal dot printer, outputs a transfer clock S_6 to the image data output unit 201, a data read signal S_1 and the transfer clock S_6 to the gradation data controller 203 and serial/parallel converter 207, a latch clock S_2 and a strobe signal S_5 to the serial/parallel converter 207, and a motor feed signal S_3 to a motor driver 213. The motor driver 213 drives a stepping motor 215 in response to the motor feed signal S_3.

The serial/parallel converter 207 converts the serial print data S_4 from the gradation data controller 203 into parallel data PD and outputs the parallel data PD to a head driver 209. The head driver 209 outputs a parallel drive signal Dd to drive a thermal print head 211.

Fig. 25 shows the structures of the essential portions of the paper feeding section of the thermal dot printer. As illustrated in this diagram, the thermal print head 211 properly presses the paper PA on a platen roller 221, made of an elastic member like rubber, at the time of printing. This produces frictional force between the platen roller 221 and the paper PA. The driving force is transmitted via a gear box 223 to the drive shaft of the platen roller 221 from the stepping motor 215. Every time the stepping motor 215 rotates by an angle corresponding to one pulse, the platen roller 221 rotates to feed just one line. The rotation of the platen roller 221 feeds the paper PA by one line in the sub scanning direction. According to the first to third embodiments, the gear ratio in the gear box 223 is set in such a way that the amount of one line feeding matches with the dot pitch P in the sub scanning direction of the thermal print head 221. According to the fourth embodiment, the gear ratio in the gear box 223 is set in such a way that the amount of one line feeding matches with $1/\sqrt{3}$ of the dot pitch P in the sub scanning direction of the thermal print head 221.

Fig. 26 shows the structures of the essential portions of the printing section of the thermal dot printer. As illustrated in this diagram, the thermal print head 211 is arranged to abut on the back of the ink ribbon IR (base film BF). The ink ribbon IR is held by a pair of ribbon rolls 225 and 227 and is fed in the direction of an arrow BB or the sub scanning direction of a printed image to be taken up on the ribbon roll 227. The paper PA abuts on the front surface of the ink ribbon IR (the layer of the ink IN) and is fed in the direction of an arrow AA in Fig. 26 or in the sub scanning direction. The platen roller 221 is intermittently driven counterclockwise indicated by an arrow EE in the diagram in synchronism with the print timing by the stepping motor 215, to thereby feed the paper PA. The ink ribbon IR is wound around the ribbon roll 227 also in synchronism with the intermittent driving of the platen roller 221. The distal end portion of thermal print head 211 where the heat generating members are arranged is urged downward in the diagram by a spring 229, properly pressing the ink ribbon IR and paper PA against the platen roller 221.

The image data output unit 201 and the gradation data controller 203 will be described below referring to Figs. 24, 27 and 28.

The image data output unit 201 stores 7-bit image data that defines the pixel gradations pixel by pixel. The 7-bit image data can indicate 128 (2^7) gray scales. The image data output unit 201 outputs the stored image data line by line in the main scanning direction. Given that a single line consists of Q dots, for example, Q dots of image data are output.

With the structure of the fourth embodiment, even-numbered heat generating members of the thermal print head 211 should be rendered inactive to print an odd-numbered line, and odd-numbered heat generating members should be rendered inactive to print an even-numbered line. To accomplish this control, the image data stored in the image data output unit 201 should be so set as to indicate the gradation of even-numbered pixels in an odd-numbered line as 0 and indicate the gradation of odd-numbered pixels in an even-numbered line as 0.

According to this embodiment, the time for applying a voltage pulse of a predetermined voltage (pulse width) is controlled in accordance with gradation data in order to control the amount of heat generated by the heat generating members. For this purpose, the print period TP for one main scanning line is divided into 127 time slots tw1 to tw127, and the heat generating elements are energized only for the time slots corresponding to the gradation after the printing has started. For instance, the heat generating members are not energized in any time slot to print dots with a gradation of 0, the heat generating members are energized in the five time slots since the beginning of the printing, i.e., in the time slots tw1 to tw5, to print dots with a gradation of 5, and the heat generating members are energized in the entire print period or the time slots tw1 to tw127 to print dots with a gradation of 127.

To ensure such energizing control, the gradation data controller 203 stores data indicating print gradations and data indicating the energization or de-energization in each time slot, both shown in Fig. 27, in the form of a table.

In accordance with the gradation data of each pixel supplied from the image data output unit 201 and the time slot for this data, the gradation data controller 203 reads associated bit data of the energizing control data and outputs it as serial data. The gradation data controller 203 performs this operation 128 times to accomplish printing of one main scanning line.

Referring now to Fig. 28, the circuit structures of the head driver 209 and the serial/parallel converter 207 will be described.

The serial/parallel converter 207 comprises a shift register 231, a latch circuit 233 and a NAND circuit 235.

The serial print data S_4 from the gradation data controller 203 is sequentially input to a terminal Din of the shift register 231 in synchronism with the data transfer clock S_6 input to a terminal CLK. The shift register 231 registers the serial print data S_4 while sequentially shifting it. When receiving one line of image data, the shift register 231 output this image data as the parallel data PD to the latch circuit 233 from output terminals O_0 to O_{Q-1}.

The latch circuit 233 latches the parallel data from the shift register 231 in synchronism with the latch clock S_2 and outputs the latched parallel data to the NAND circuit 235.

The NAND circuit 235 has a plurality of NAND gates each of which receives the strobe signal S_5 at one input terminal and an associated bit in the parallel data from the latch circuit 233 at the other input terminal. Each NAND gate outputs the associated bit signal inverted to the head driver 209 while the strobe signal S_5 has a level "1."

The head driver 209 inverts and amplifies the output of the NAND circuit 235 by Q inverters (inverter amplifiers), and outputs the resultant signals as a parallel output Dd to the thermal print head 211.

The thermal print head 211 has one main scanning line of heat generating members, e.g., Q heat generating members (or heat generating portions) which generate heat when receiving data (pulses) "1" from the associated inverters. The outputs of the inverters are equivalent to the voltages of the segment electrodes 103 shown in Figs. 11A and 11B. The input S_7 to the thermal print head 211 is equivalent to the voltage of the common electrode 102 in Figs. 11A and 11B, and is fixed to, for example, the ground voltage.

The printing control operation of the thermal print head with the above-described structure will be described with reference to the timing charts given in Figs. 29A to 29G.

Fig. 29A shows the operation timing, Fig. 29B shows the waveform of the data read clock S_1, Fig. 29C shows the waveform of the serial print data S_4, Fig. 29D shows the waveform of the latch clock S_2, Fig. 29E shows the waveform of the strobe signal S_5, Fig. 29F shows the waveform of the print head output Dd, and Fig. 29G shows the waveform of the motor feed signal S_3.

As shown in Fig. 29A, this thermal dot printer alternately performs a process of heating the heat generating elements to print one line in the main scanning direction and a process of feeding the paper and ink ribbon to print an image. Each print period TP is divided into 127 time slots tw1 to tw127.

First, the control pulse generator 205 sends the signal S_0 to the image data output unit 201 to cause this output unit 201 to output image data SD of individual pixels on one line to be printed next to the gradation data controller 203, during the feed period TM. The gradation data controller 203 holds the received image data SD.

Next, the control pulse generator 205 outputs the data read clock S_1. The gradation data controller 203 selects bit data for the time slot tw1 shown in Fig. 27 in accordance with the image data SD in synchronism with the data read clock S_1, and outputs the bit data bit by bit as serial data S_4 in response to the transfer clock S_6. In other words, the gradation data controller 203 outputs bit data "0" for the pixels whose image data is (0000000) and outputs bit data "1" for the pixels which have image data of (0000001) to (1111111).

The serial data S_4 is supplied to the shift register 231 in the serial/parallel converter 207.

The shift register 231 sequentially receives the supplied serial data S_4 in synchronism with the transfer clock S_6. When the entire serial data S_4 is registered in the shift register 231 and the print period TP starts, the control pulse generator 209 outputs the latch clock S_2 and the strobe signal S_5 as shown in Figs. 29D and 29E.

In response to the latch clock S_2, the one line of data held in the shift register 231 is latched in the latch circuit 233.

In response to the strobe signal S_5, the NAND circuit 235 is enabled to allow the data held in the latch circuit 233 to be supplied as initial print data to the heat generating elements via the inverters of the head driver 209. Those heat generating elements which receive data "1" are selectively energized to generate heat.

In synchronism with the latch clock S_2 or with a slight delay from the reception thereof, the control pulse generator 205 outputs the data read clock S_1. In response to the data read clock S_1, the gradation data controller 203 selects the energizing control data for the time slot tw2 shown in Fig. 27 in accordance with the image data of individual pixels and outputs the data as the serial data S_4. In other words, the gradation data controller 203 outputs bit data "0" for the pixels which have image data of (0000000) and (0000001) and outputs bit data "1" for the pixels which have image data of (0000010) to (1111111).

When one line of data is registered in the shift register 231 and a given period tw passes since the previous output of the latch clock S_2, the control pulse generator 205 outputs the latch clock S_2 as shown in Fig. 29D and writes one line of data, held in the shift register 231, into the latch circuit 233.

As shown in Fig. 29F, the strobe signal S_5 is enabled and the NAND circuit 235 is enabled. Therefore, the data held in the latch circuit 233 is applied to the heat generating elements via the NAND circuit 235 and the head driver 209.

The above-described operation is repeated 127 times to complete one line printing.

With the above structure, for example, the heat generating members for printing pixels of gradation 0 are not energized, the heat generating members for printing pixels of gradation 5 are energized only for a period of 5tw, and the heat generating members for printing pixels of gradation 100 are energized only for a period of 100tw, so that heat energy whose amount is proportional to the energizing time is generated. Accordingly, the area of ink to be transferred changes in accordance with image data and the gradation corresponding to the image data is obtained.

Then, the control pulse generator 205 outputs the motor feed signal S_3 to feed the paper PA and ink ribbon IR in the sub scanning direction by the dot pitch. This amount of feeding is the same as the dot pitch in the main scanning direction in the first to third embodiments, and is $1/\sqrt{3}$ of the dot pitch in the main scanning direction in the fourth embodiment.

Thereafter, the process of printing one line in the main scanning direction and the process of feeding the paper PA and ink ribbon IR are sequentially repeated.

The feed period TM changes in accordance with a change in the feed speed of the stepping motor M_2. Therefore, the general feeding operation of the stepping motor M_2 affects the speed of the printing process.

For color printing, the ink ribbon IR in use has a yellow ink region, a magenta ink region and a cyan ink region in order in the sub scanning direction as shown in Fig. 30, for example. The image data output unit 201 stores data indicating the color and gradation of each pixel as image data. As apparent from the procedures shown in Fig. 31, a specific number of lines are printed for yellow pixels (step S1). Then, the paper PA is fed by the specific number of lines in the reverse direction, and the ink ribbon IR is fed in the forward direction to the magenta ink region (step S2). Then, a specific number of lines are printed for magenta pixels (step S3), after which the ink ribbon IR is fed in the forward direction to the cyan ink region (step S4). Next, a specific number of lines are printed for cyan pixels (step S5), after which the ink ribbon IR is fed in the forward direction to the yellow ink region (step S6).

In the above-described manner, a specific number of lines are printed with each of yellow, magenta and cyan inks using three ink regions on the ink ribbon IR, thereby providing a full-colored image.

It is then determined whether or not the printing is completed. If the printing is not complete, the above-described processing is repeated.

The present invention is not limited to the above-described embodiments, but may be modified and adapted in various forms. For example, although the image data has a data length of 7 bits in those embodiments, the data length can be changed in accordance with the requested number of gradations.

Although the ink ribbon IR having a heat-meltable ink layer formed thereon and the paper PA are used as the print medium in the above-described embodiments, other print media may be used as well. For instance, this invention may be adapted for a thermal dot printer which uses an ink ribbon IR having a thermal sublimation type ink layer formed thereon and a paper PA, or a thermal dot printer which uses a thermosensible paper or inc ribbon that produces dots with gradations corresponding to the amount of applied heat.

Although the energization time for the heat generating elements is controlled by changing the number of pulses applied to the heat generating elements to thereby control the amount of heat generated by each heat generating element in the above-describe embodiments, the energization time for the heat generating elements may be changed using other schemes. Further, while the energization time is set constant, the applied voltage to the heat generating elements may be controlled. Furthermore, the energization time and the applied voltage are both controlled properly.

In the above-described embodiments, the paper PA and ink ribbon IR are fed in the sub scanning direction after printing of one line in the main scanning direction is completed. If the print medium and the heat generating elements can be moved relative to each other, either the print medium or the heat generating elements or both may be moved.

Claims

1. A thermal dot printer comprising:

a plurality of heat generating elements (101, 115) aligned in a main scanning direction;

feeding means (213, 215) for moving a print medium (IR, PA) in a sub scanning direction in relative to said heat generating elements (101, 115); and

control means (201 to 211), connected to said heat generating elements (101, 115), for variably controlling energy to be applied to said heat generating elements (101, 115) to change areas of printed dots of said print medium (PA, IR), thereby forming a gradation image, and controlling said feeding means (213, 215) to feed said print medium (IR, PA), characterized in that

a size Lm of each of said heat generating elements (101, 115) in said main scanning direction and an arranging pitch DOPm of said heat generating elements (101, 115) in said main scanning direction have a relationship of $Lm \leqq DOPm \times (2/3)$, a size Ls of each of said heat generating elements in said sub scanning direction have a relationship of $Lm < Ls \leqq DOPs$ with respect to a pitch DOPs, determined by an amount of relative movement of said print medium (IR, PA) by said feeding means (213, 215) and a printing timing, and said size Lm of said heat generating elements (101, 115) in said main scanning direction.

2. The thermal dot printer according to claim 1, wherein said print medium comprises an ink ribbon (IR) having ink regions of different colors and a sheet (PA) on which inks (IN) on said ink ribbon are transferred to form a gradation image, and

said control means (201 to 211) repeats printing with said inks (IN) of different colors to print a full-colored image.

3. The thermal dot printer according to claim 1, wherein said control means (201 to 211) includes means for controlling an energization time for said heat generating elements (101, 115).

4. The thermal dot printer according to claim 1, wherein said print medium comprises an ink ribbon (IR) having a base film (BF) and an ink layer (IN) formed on said base film, and a sheet (PA) on which an ink (IN) on said ink ribbon (IR) is transferred to form a gradation image, and

said base film (BF) has a thickness of 5 μm or below.

5. The thermal dot printer according to claim 1, wherein said heat generating elements (101, 115) have substantially a convex outline.

6. A thermal dot printer comprising:

a plurality of heat generating elements (101, 115) aligned in a main scanning direction;

feeding means (213, 215) for moving a print medium (IR, PA) in a sub scanning direction in relative to said heat generating elements (101, 115); and

control means (201 to 211), connected to said heat generating elements (101, 115), for variably controlling energy to be applied to said heat generating elements (101, 115) to change areas of printed dots of said print medium (IR, PA), thereby forming a gradation image, and controlling said feeding means (213, 215) to feed said print medium (IR, PA), characterized in that

a size Lm of each of said heat generating elements (101, 115) in said main scanning direction and an arranging pitch DOPm of said heat generating elements (101, 115) in said main scanning direction have a relationship of $Lm \leqq DOPm \times (2/3)$, a size Ls of each of said heat generating elements (101, 115) in said sub scanning direction having a relationship of $Ls \leqq DOPs$ with respect to a pitch DOPs, determined by an amount of relative movement of said print medium (IR, PA) by said feeding means (213, 215) and a printing timing.

7. The thermal dot printer according to claim 6, wherein said print medium comprises an ink ribbon (IR) having ink regions of different colors and a sheet (PA) on which inks (IN) on said ink ribbon (IR) are transferred to form a gradation image, and

said control means (201 to 211) repeats printing with said inks of different colors to print a full-colored image.

8. The thermal dot printer according to claim 6, wherein said control means (201 to 211) includes means for controlling an energization time for said heat generating elements (101, 115).

9. The thermal dot printer according to claim 6, wherein said print medium comprises an ink ribbon (IR) having a base film (BF) and an ink layer (IN) formed on said base film (BF), and a sheet (PA) on which an ink (IN) on said ink ribbon is transferred to form a gradation image, and

said base film (BF) has a thickness of 5 μm or below.

10. The thermal dot printer according to claim 6, wherein said heat generating elements (101, 115) have substantially a convex outline.

11. A thermal dot printer comprising:

a thermal print head (211) including a plurality of heat generating elements (101, 115) aligned in a main scanning direction;

control means (201 to 209) for energizing said heat generating elements (101, 115) to generate heat therefrom, thereby forming a dot image on a print medium (PA); and

feeding means (205, 213, 215) for feeding said thermal print head (211) and said print medium (PA, IR) in relative to each other every time one-line print in said main scanning direction is completed, said feeding means including feeding control means (205) for performing control so as to set an amount of relative movement of said thermal print head (211) and said print medium (IR, PA) to $P/\sqrt{3}$ where P is an arranging pitch of said heat generating elements (101, 115) in said main scanning direction,

said control means (201 to 209) energizing odd-numbered heat generating elements (101, 115) of said thermal print head (211) on an N-th line in the sub scanning direction and energizing even-numbered heat generating elements (101, 115) on an (N+1)-th line in the sub scanning direction.

12. The thermal dot printer according to claim 11, wherein said print medium comprises an ink ribbon (IR) having ink regions of different colors and a sheet (PA) on which inks (IN) on said ink ribbon (IR) are transferred to form a gradation image, and

said control means (201 to 209) repeats printing with said inks (IN) of different colors to print a full-colored image.

13. The thermal dot printer according to claim 11, wherein said control means (201 to 209) includes means (201 to 207), for controlling an energization time for said heat generating elements (101, 115).

14. The thermal dot printer according to claim 11, wherein said print medium comprises an ink ribbon (IR) having a base film (BF) and an ink layer formed on said base film (BF), and a sheet (PA) on which an ink (IN) on said ink ribbon (IR) is transferred to form a gradation image, and

said base film (BF) has a thickness of 5 μm or below.

15. The thermal dot printer according to claim 11, wherein said heat generating elements (101, 115) have substantially a convex outline.

16. A thermal dot printer comprising:

a thermal print head (211) including a plurality of heat generating elements (121) aligned in a main scanning direction, and electrodes (122, 123), connected to both ends of said heat generating elements (121) in a sub scanning direction, for supplying a current to said heat generating elements (121) to generate heat therefrom; and

control means (201 to 209), connected to said electrodes, for variably controlling energy to be applied to said heat generating elements (121) to change areas of printed dots of a print medium (IR, PA), thereby forming a gradation image, characterized in that

a width T of connecting portions of said heat generating elements and said electrodes and a size Lm of said heat generating elements (121) in said main scanning direction have a relationship of $T \leqq Lm \times (2/3)$.

17. The thermal dot printer according to claim 16, wherein said size Lm of said heat generating elements (121) in said main scanning direction is set to have a relation of $Lm \leqq P \times (2/3)$ with respect to an arranging pitch of said heat generating elements (121) in said main scanning direction.

18. The thermal dot printer according to claim 16, wherein said print medium comprises an ink ribbon (IR, PA) having ink regions of different colors and a paper (PA) on which inks (IN) on said ink ribbon (IR) are transferred to form a gradation image, and

said control means (201 to 209) repeats printing with said inks (IN) of different colors to print a full-colored image.

19. The thermal dot printer according to claim 16, wherein said control means (201 to 209) includes means (201 to 207) for controlling an energization time for said heat generating elements (121).

20. The thermal dot printer according to claim 16, wherein said print medium comprises an ink ribbon (IR) having a base film (BF) and an ink layer (IN) formed on said base film (BF), and a sheet (PA) on which an ink (IN) on said ink ribbon (IR) is transferred to form a gradation image, and

said base film (BF) has a thickness of 5 μm or below.

21. The thermal dot printer according to claim 16, wherein said heat generating elements (121) have substantially a convex outline.

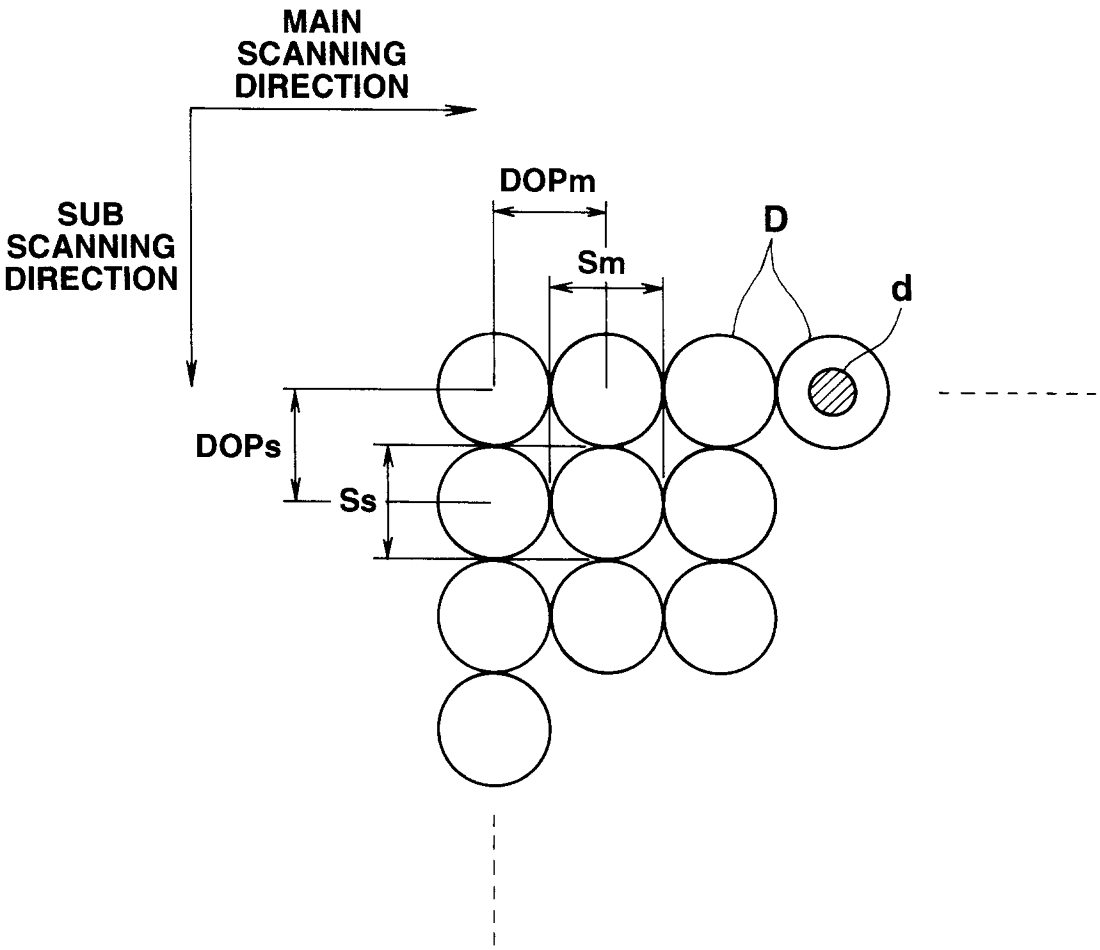


FIG.1
(PRIOR ART)

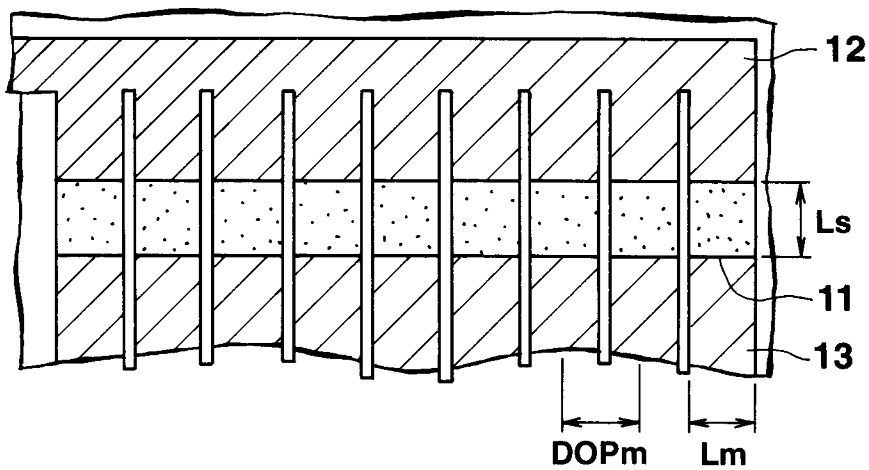


FIG.2A
(PRIOR ART)

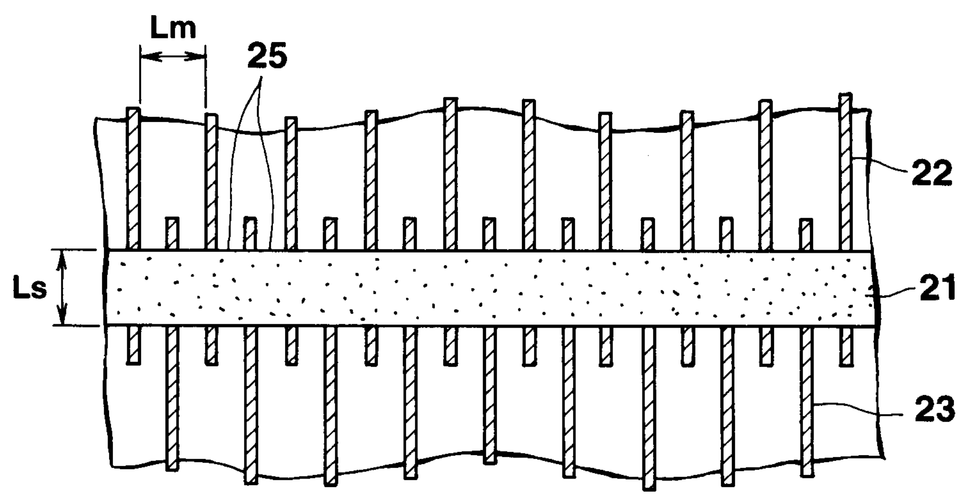


FIG.2B
(PRIOR ART)

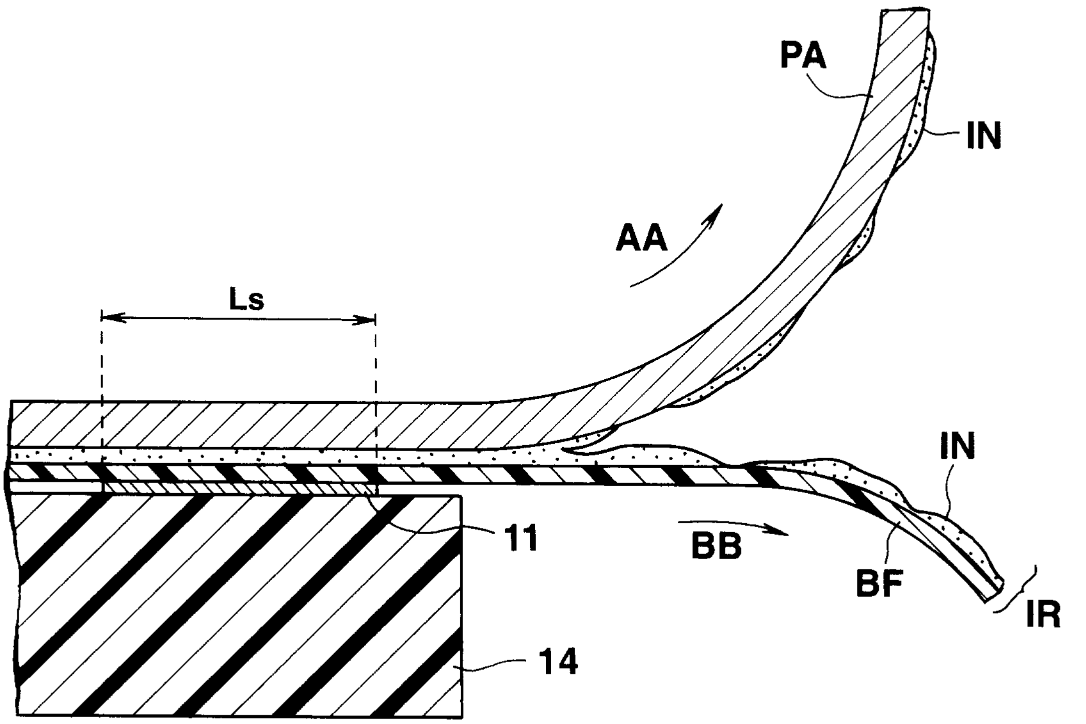


FIG.3
(PRIOR ART)

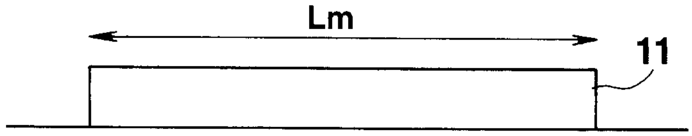


FIG.4A
(PRIOR ART)

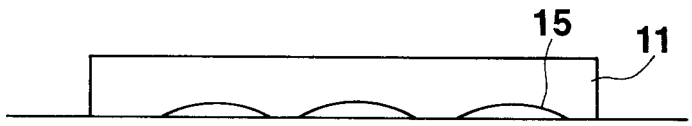


FIG.4B
(PRIOR ART)

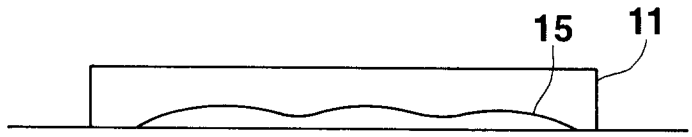


FIG.4C
(PRIOR ART)

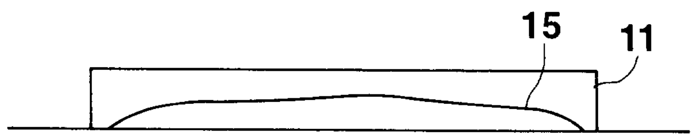


FIG.4D
(PRIOR ART)

FIG.4E
(PRIOR ART)

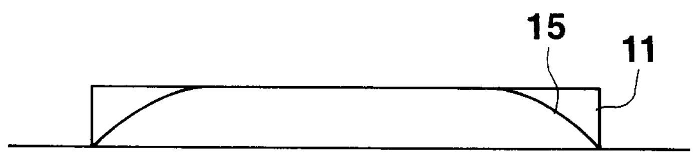


FIG.4F
(PRIOR ART)

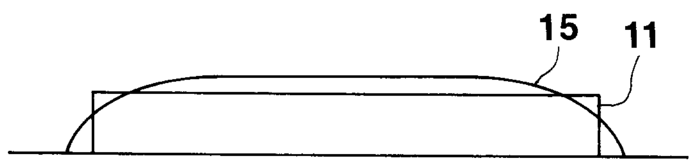


FIG.4G
(PRIOR ART)

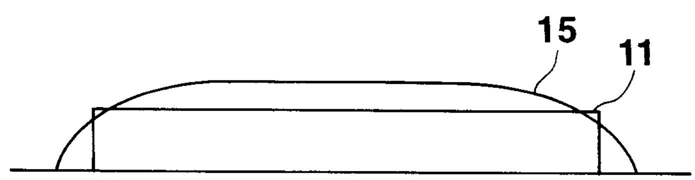


FIG.4H
(PRIOR ART)

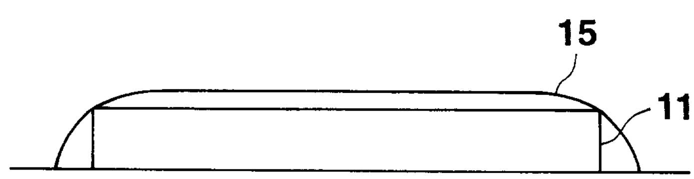


FIG.4I
(PRIOR ART)

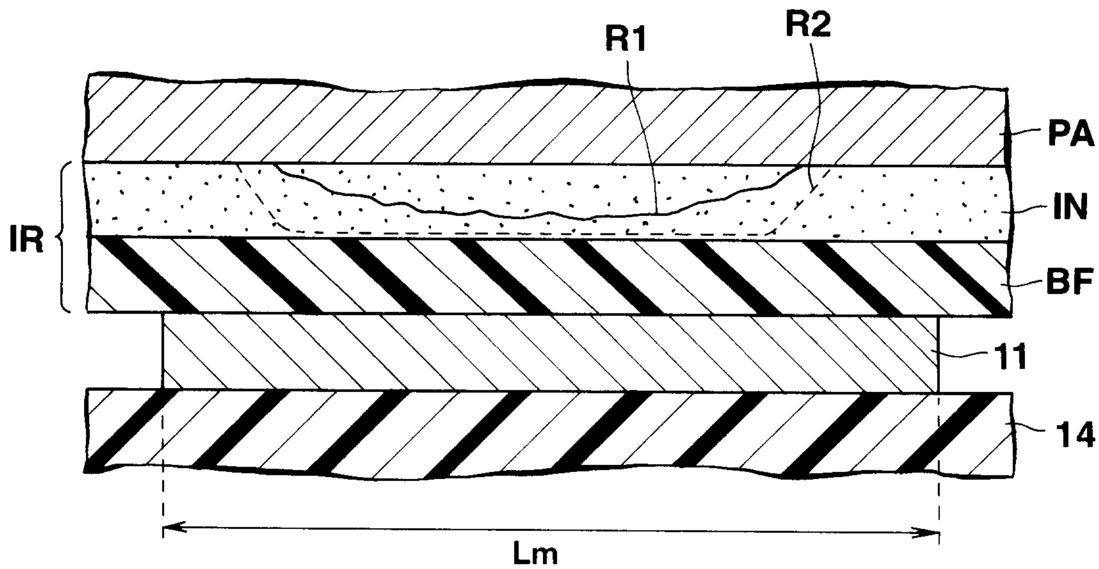


FIG.5
(PRIOR ART)

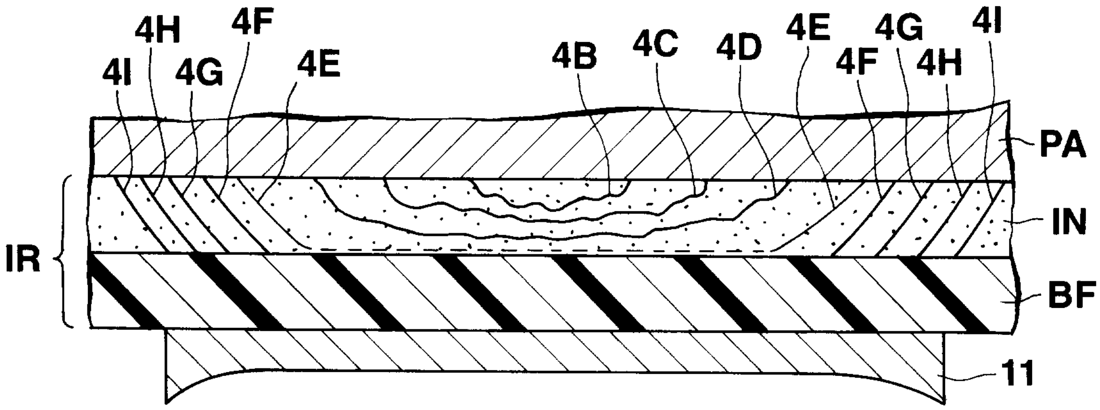


FIG.6
(PRIOR ART)

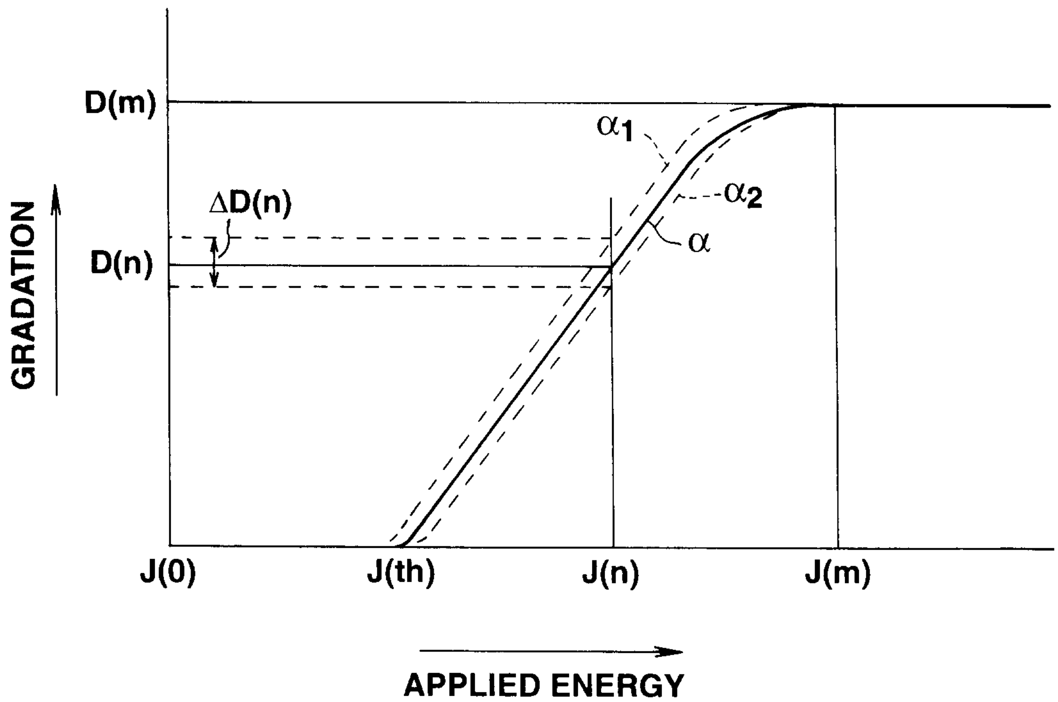


FIG.7
(PRIOR ART)

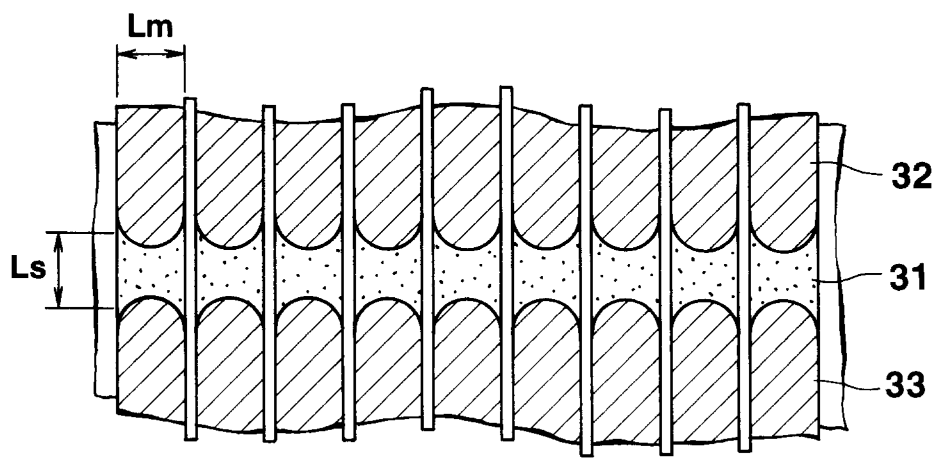


FIG.8
(PRIOR ART)

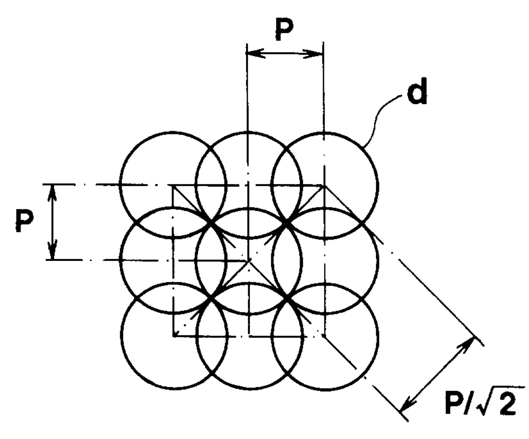


FIG.9
(PRIOR ART)

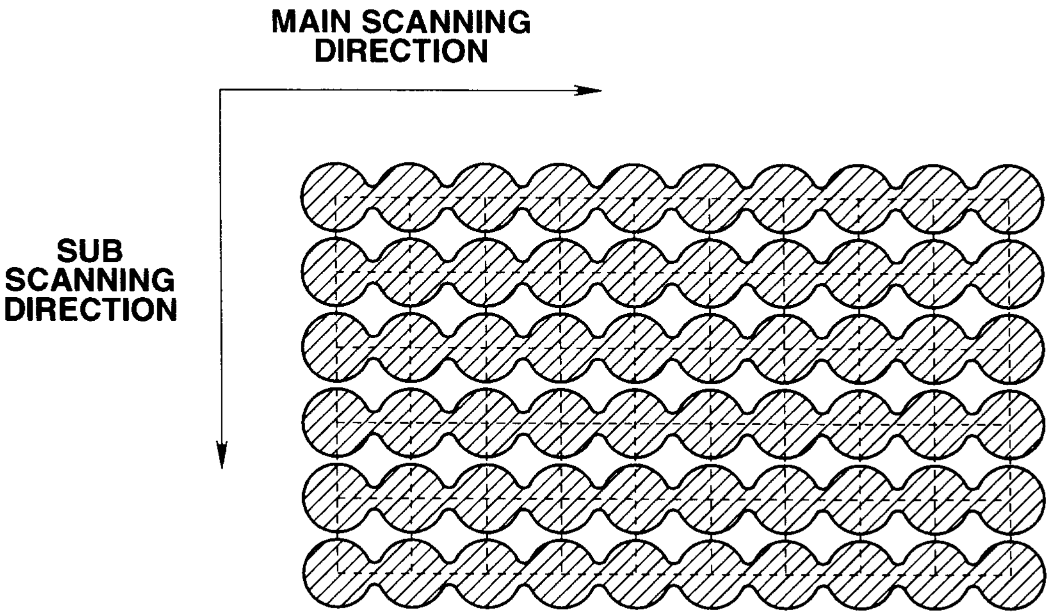


FIG.10
(PRIOR ART)

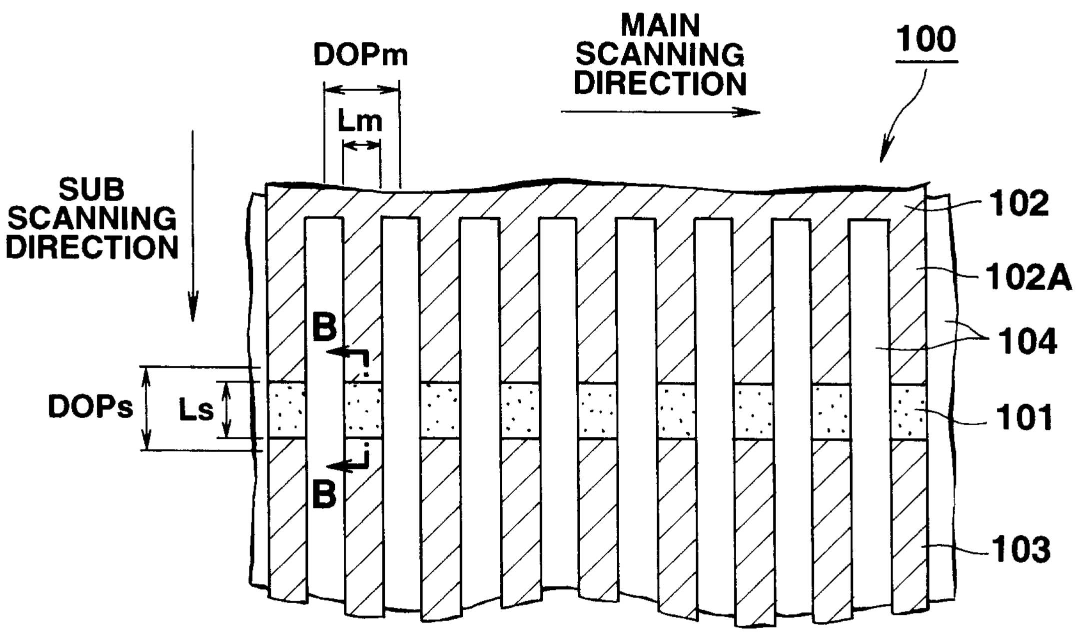


FIG.11A

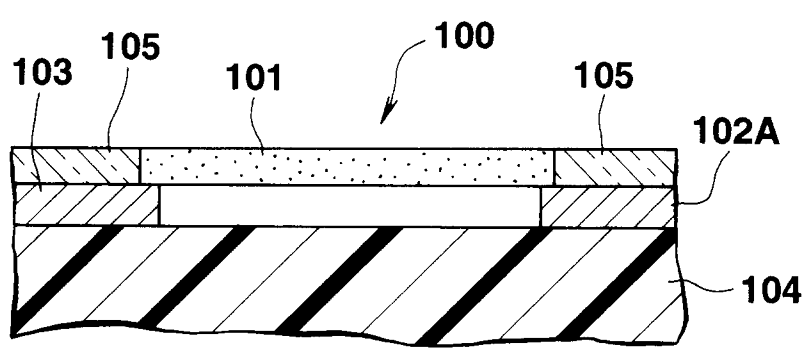


FIG.11B

FIG.12A

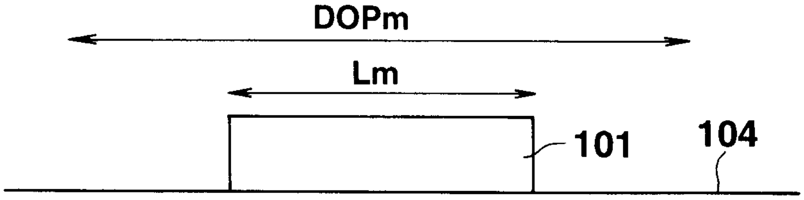


FIG.12B

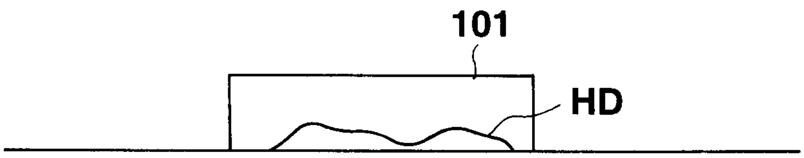


FIG.12C

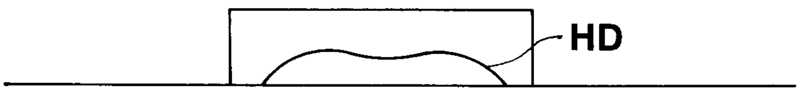


FIG.12D

FIG.12E

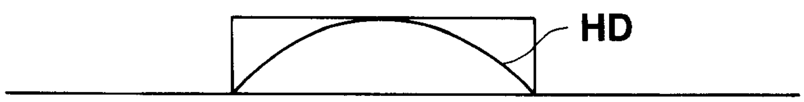


FIG.12F

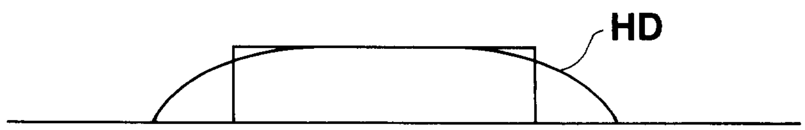


FIG.12G

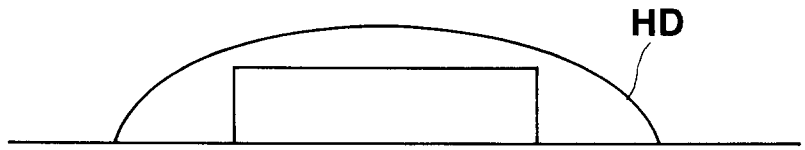
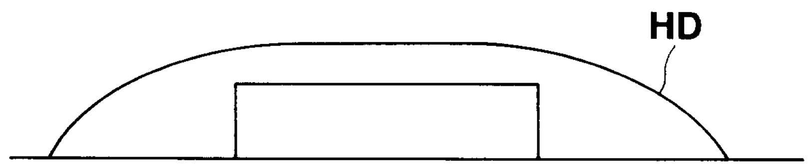


FIG.12H



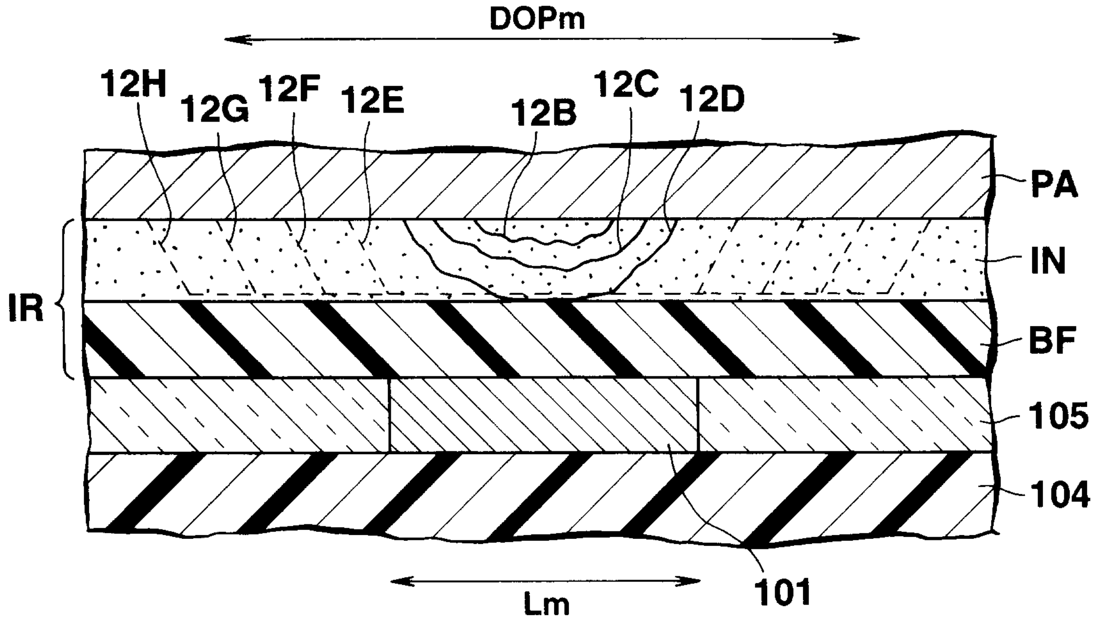

DOPm
12H
12G
12F
12E
12B
12C
12D
PA
IN
IR
BF
105
104
Lm
101

FIG.13

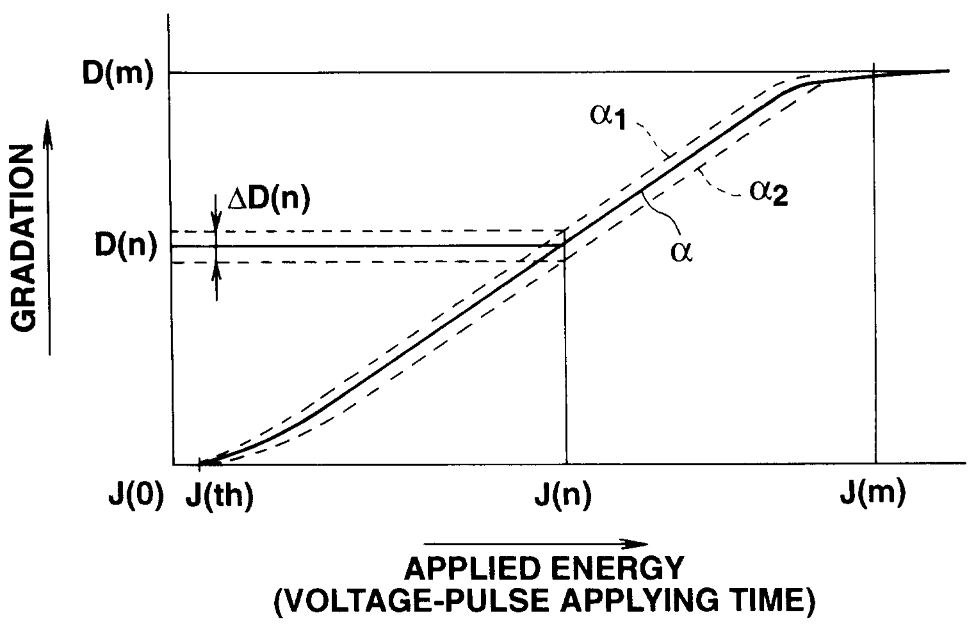

D(m)
GRADATION
ΔD(n)
D(n)
α1
α2
α
J(0)
J(th)
J(n)
J(m)
APPLIED ENERGY
(VOLTAGE-PULSE APPLYING TIME)

FIG.14

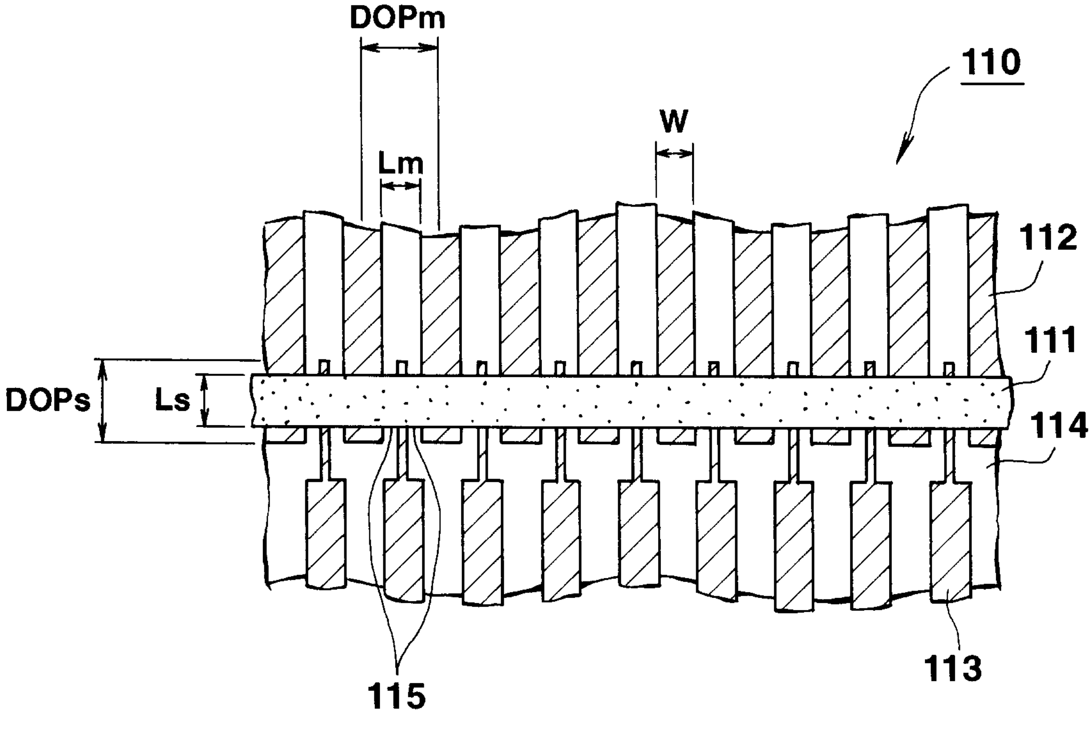


FIG.15

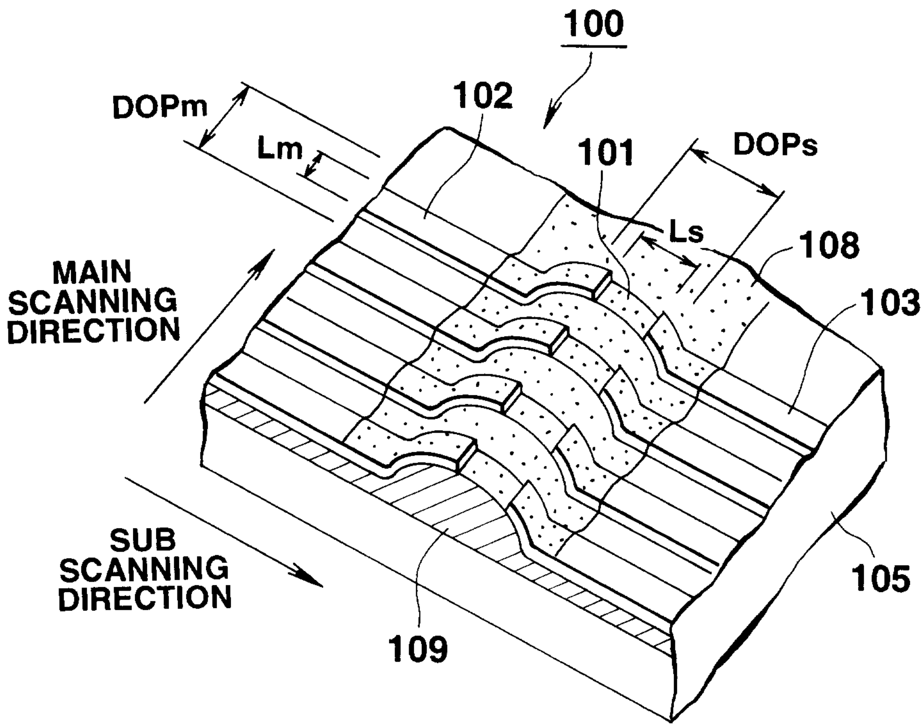

100
DOPm
Lm
102
101
DOPs
Ls
108
103
MAIN
SCANNING
DIRECTION
SUB
SCANNING
DIRECTION
105
109

FIG.16

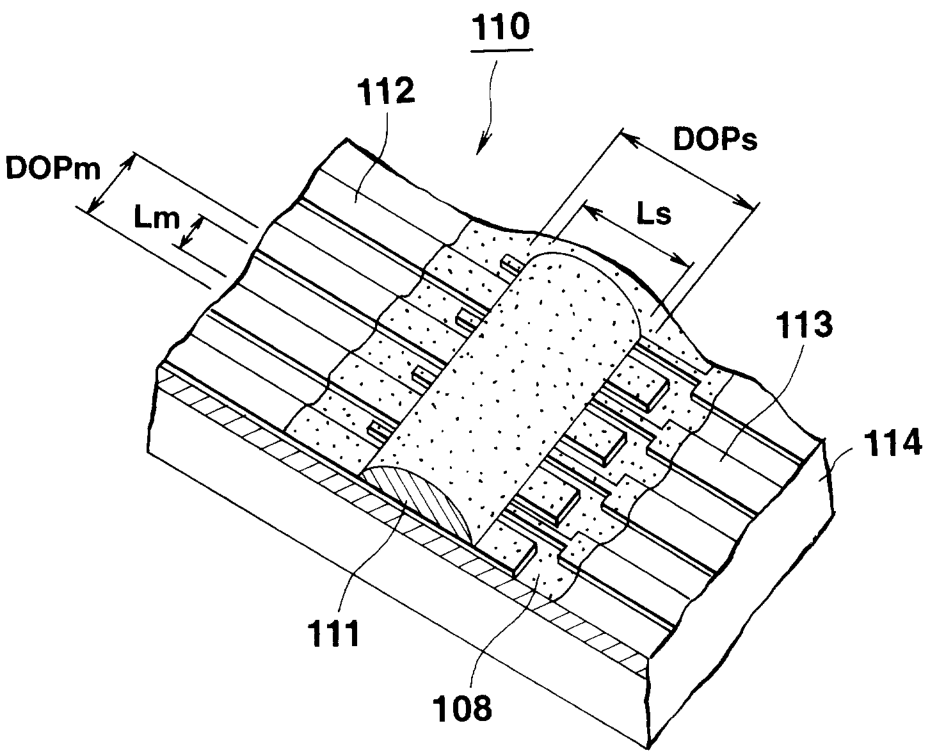

110
112
DOPs
DOPm
Lm
Ls
113
114
111
108

FIG.17

NO.	DOPm (μm)	DOPs (μm)	Lm(μm)	Ls(μm)	PRINT RESULT	DOT PITCH
1	139	139	139	139	×	139μm
2	139	139	120	139	×	
3	139	139	100	139	△	
4	139	139	90	139	◎	
5	139	139	80	139	◎	
6	139	139	70	90	◎	
7	139	139	139	120	×	
8	139	139	90	80	×	
9	125	125	125	125	×	125μm
10	125	125	100	125	×	
11	125	125	90	125	△	
12	125	125	80	125	◎	
13	125	125	70	125	◎	
14	125	125	60	100	◎	
15	125	125	125	120	×	
16	125	125	100	90	×	

FIG.18

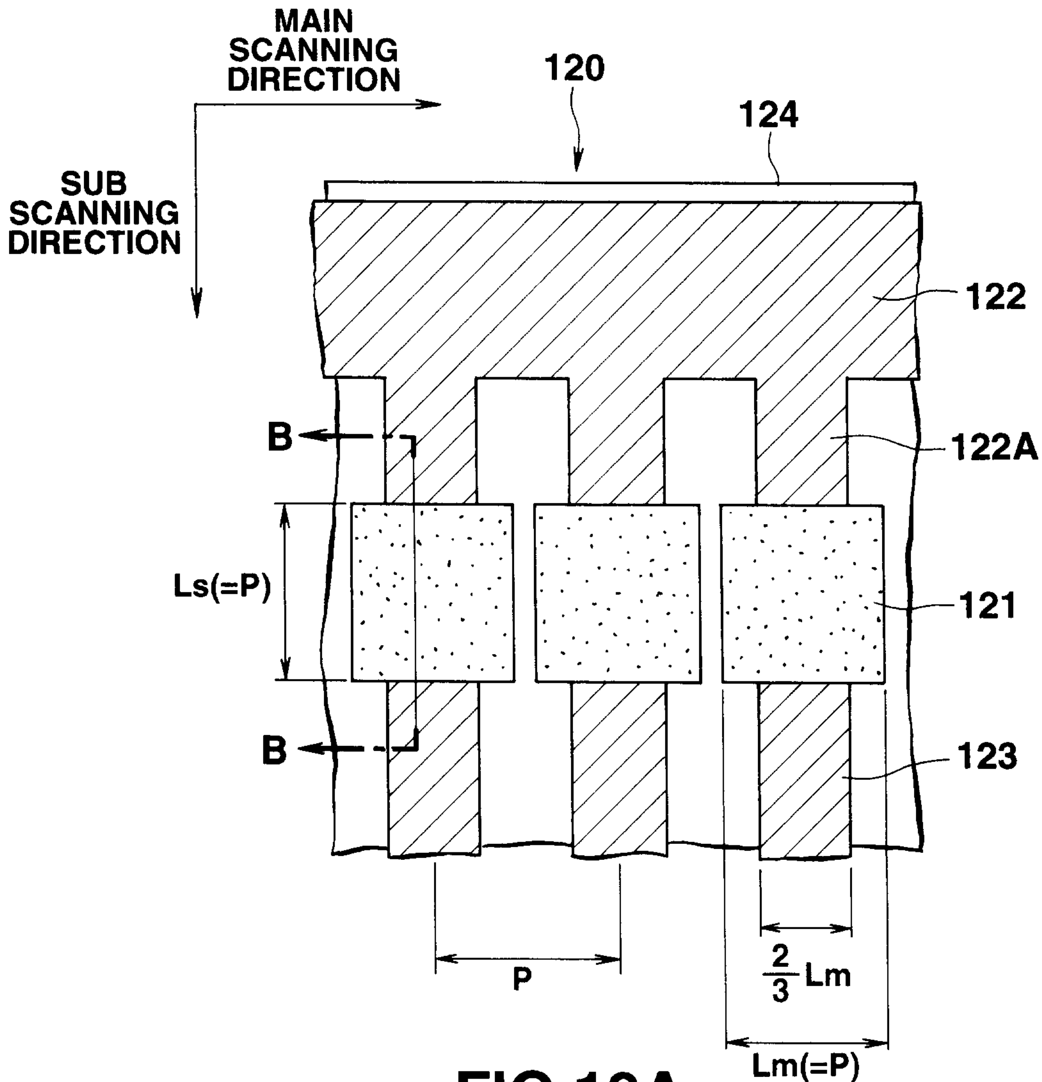


FIG.19A

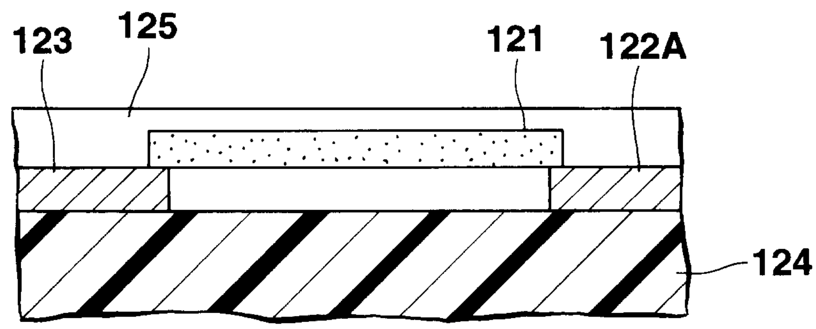


FIG.19B

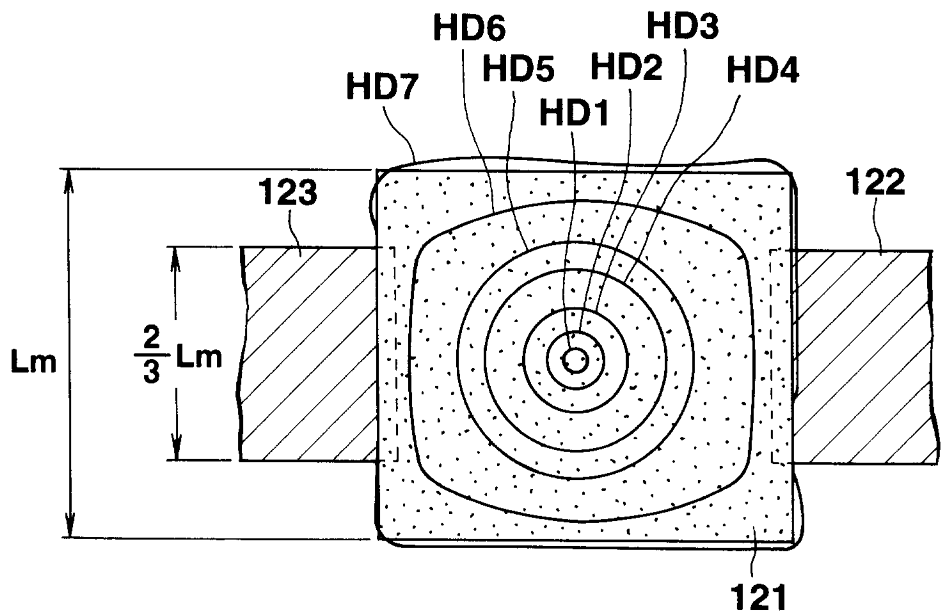


FIG.20A

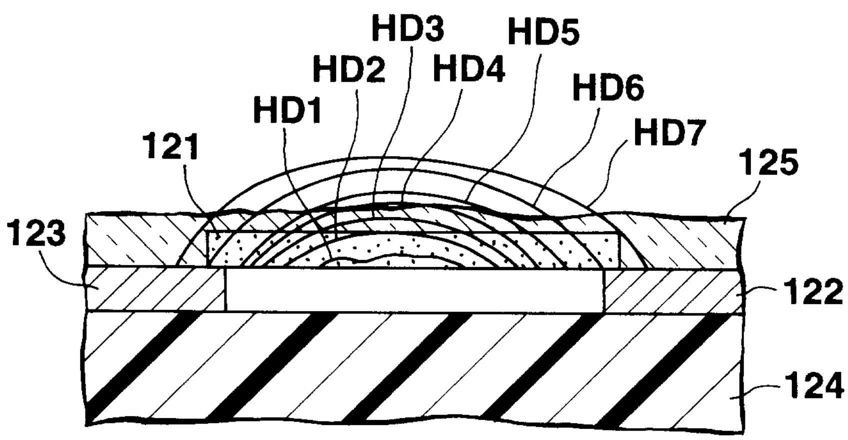


FIG.20B

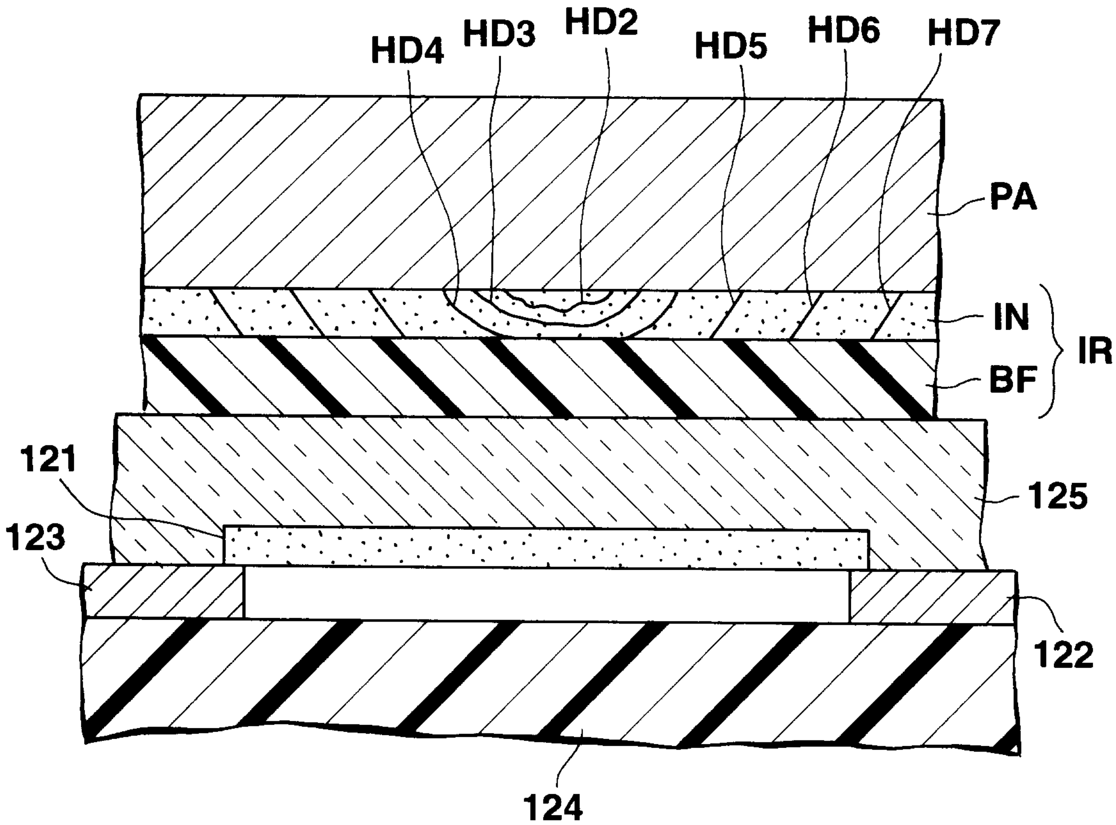


FIG.21

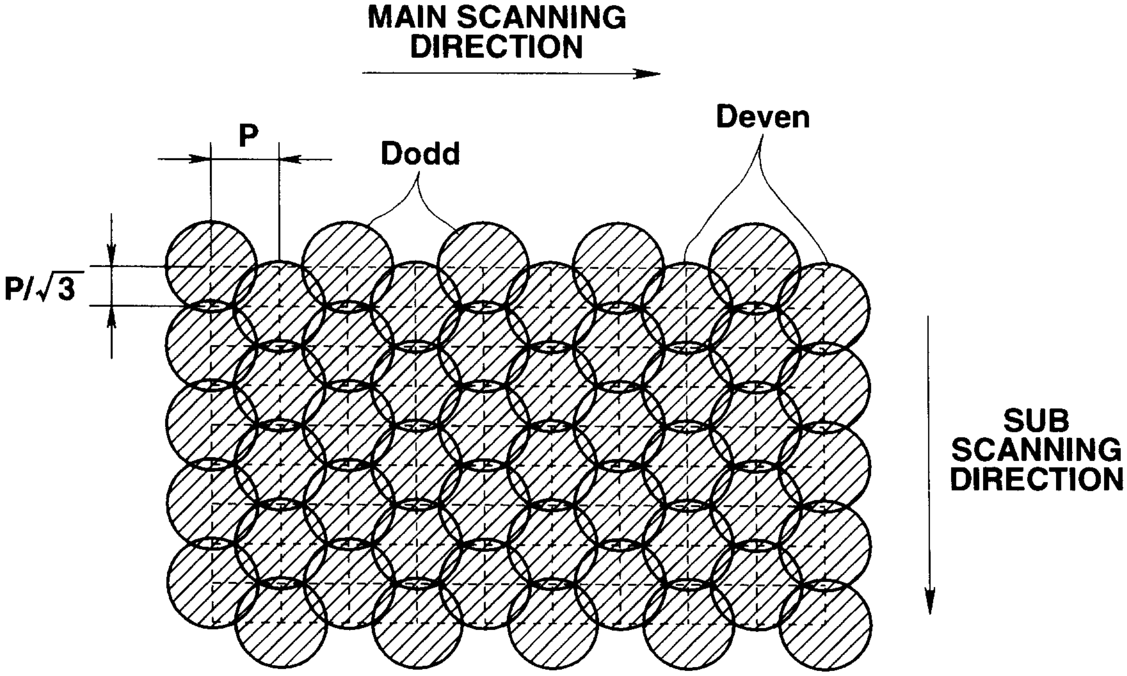


FIG.22A

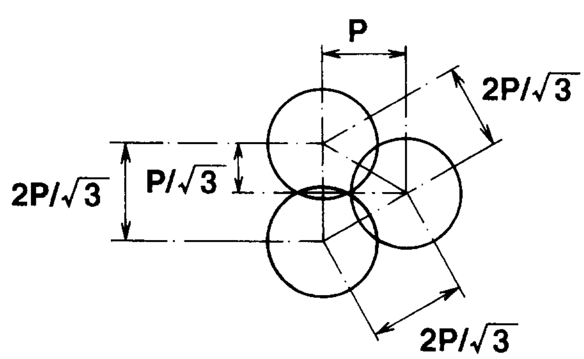


FIG.22B

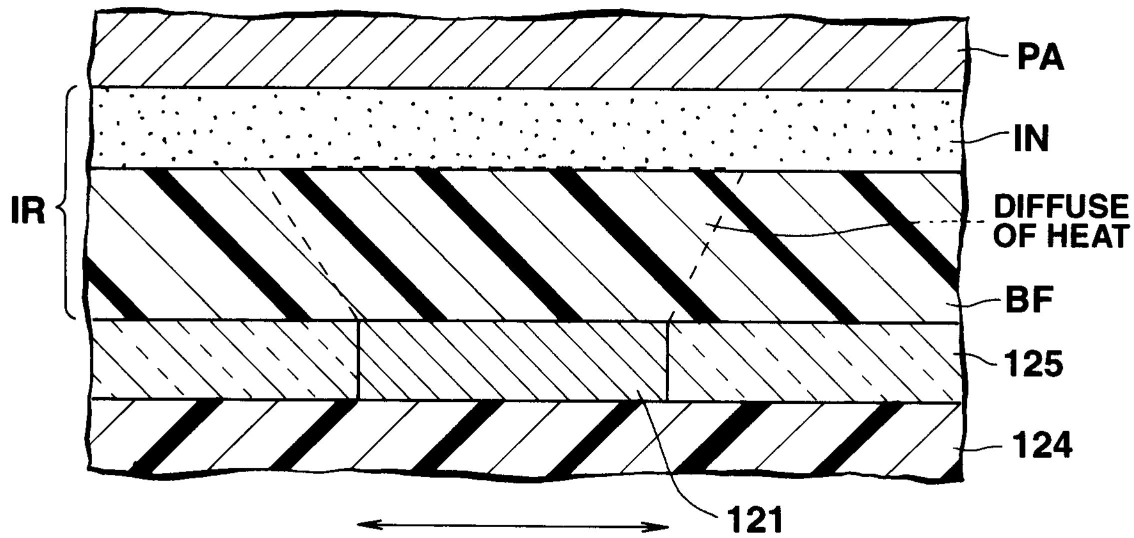


FIG.23A

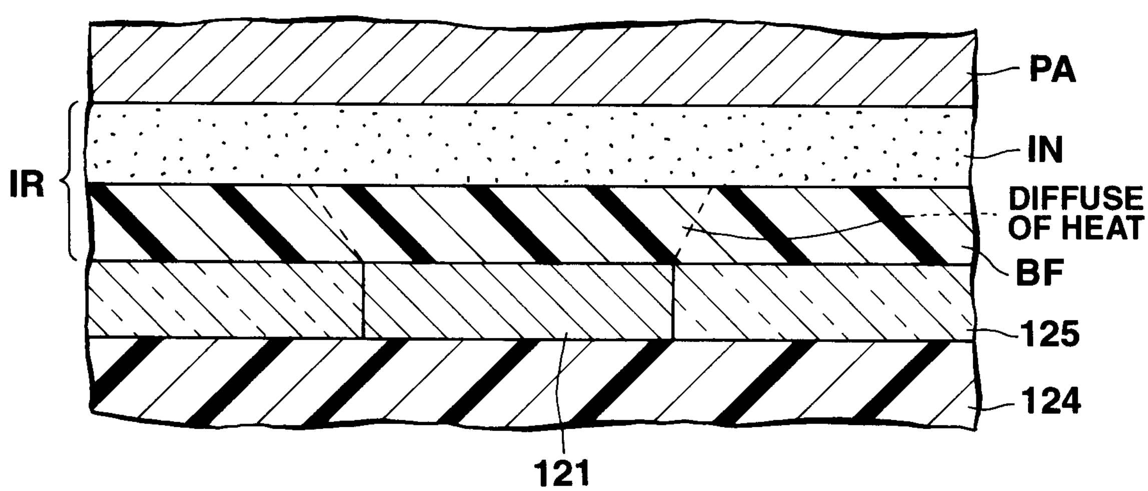


FIG.23B

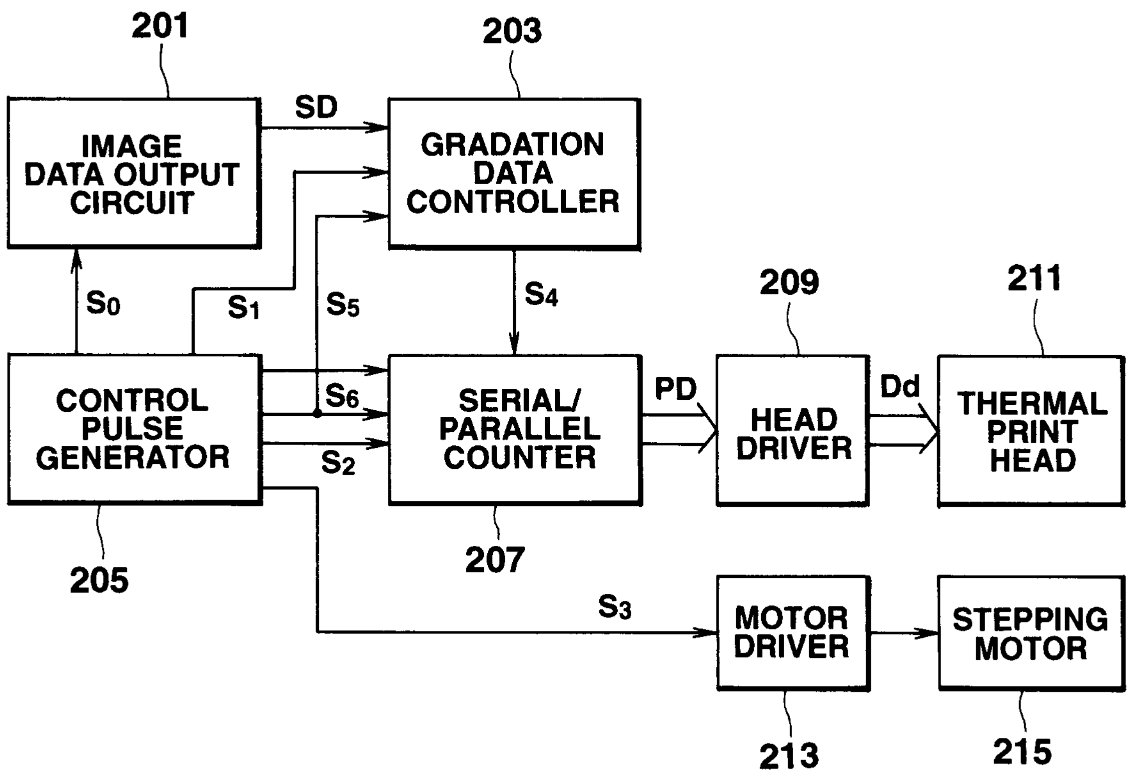

201
203
SD
IMAGE DATA OUTPUT CIRCUIT
GRADATION DATA CONTROLLER
S0
S1
S5
S4
209
211
CONTROL PULSE GENERATOR
S6
S2
SERIAL/ PARALLEL COUNTER
PD
HEAD DRIVER
Dd
THERMAL PRINT HEAD
205
207
S3
MOTOR DRIVER
STEPPING MOTOR
213
215

FIG.24

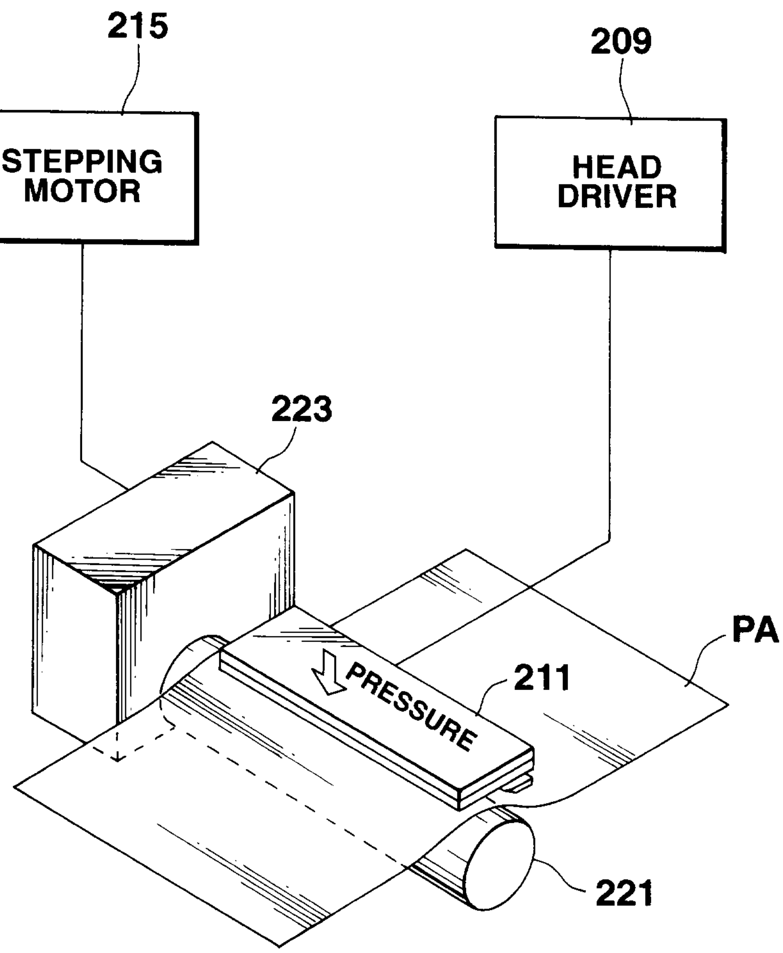


FIG.25

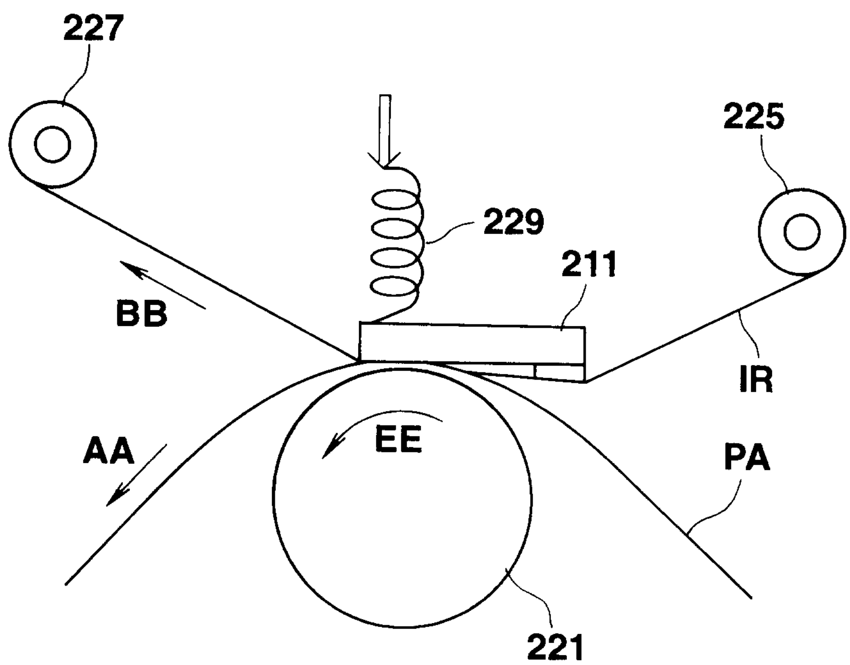


FIG.26

IMAGE DATA	ENERGIZING CONTROL DATA
0000000	0 0 0 0 0 0 0 ••••••• 0 0 0
0000001	1 0 0 0 0 0 0 ••••••• 0 0 0
0000010	1 1 1 0 0 0 0 ••••••• 0 0 0
0000011	1 1 1 1 0 0 0 ••••••• 0 0 0
0000100	1 1 1 1 1 0 0 ••••••• 0 0 0
0000101	1 1 1 1 1 1 0 ••••••• 0 0 0
0000110	1 1 1 1 1 1 1 ••••••• 0 0 0
••••••	••••••
••••••	••••••
••••••	••••••
1111101	1 1 1 1 1 1 1 ••••••• 1 0 0
1111110	1 1 1 1 1 1 1 ••••••• 1 1 0
1111111	1 1 1 1 1 1 1 ••••••• 1 1 1

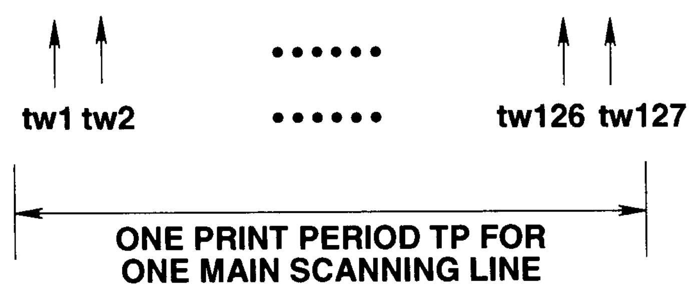


FIG.27

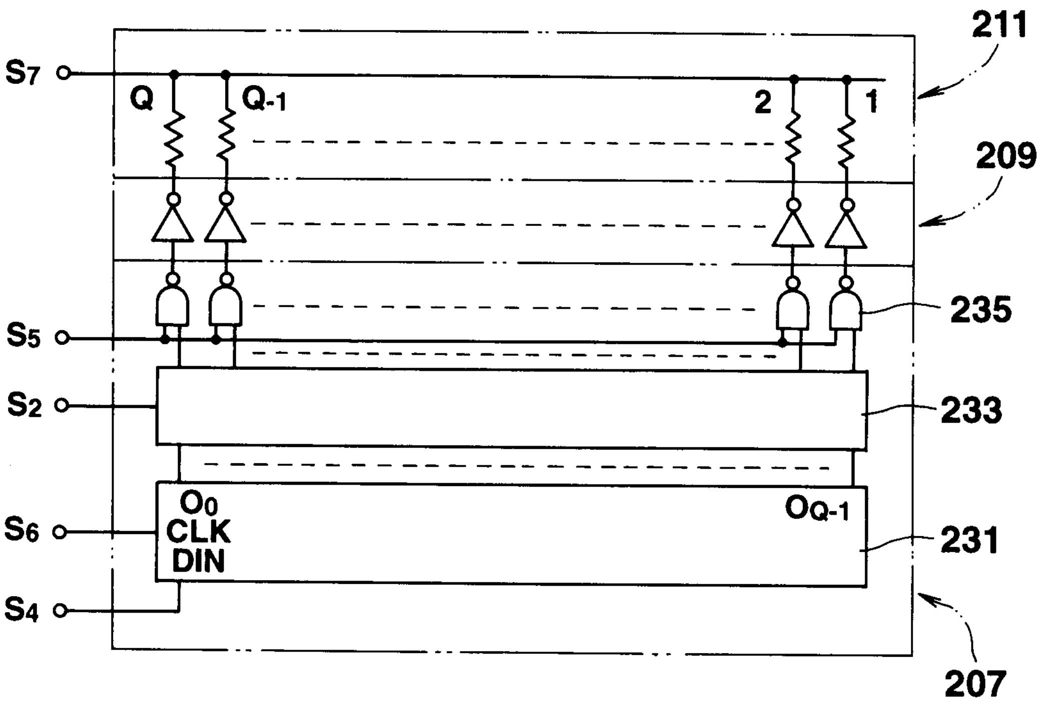


FIG.28

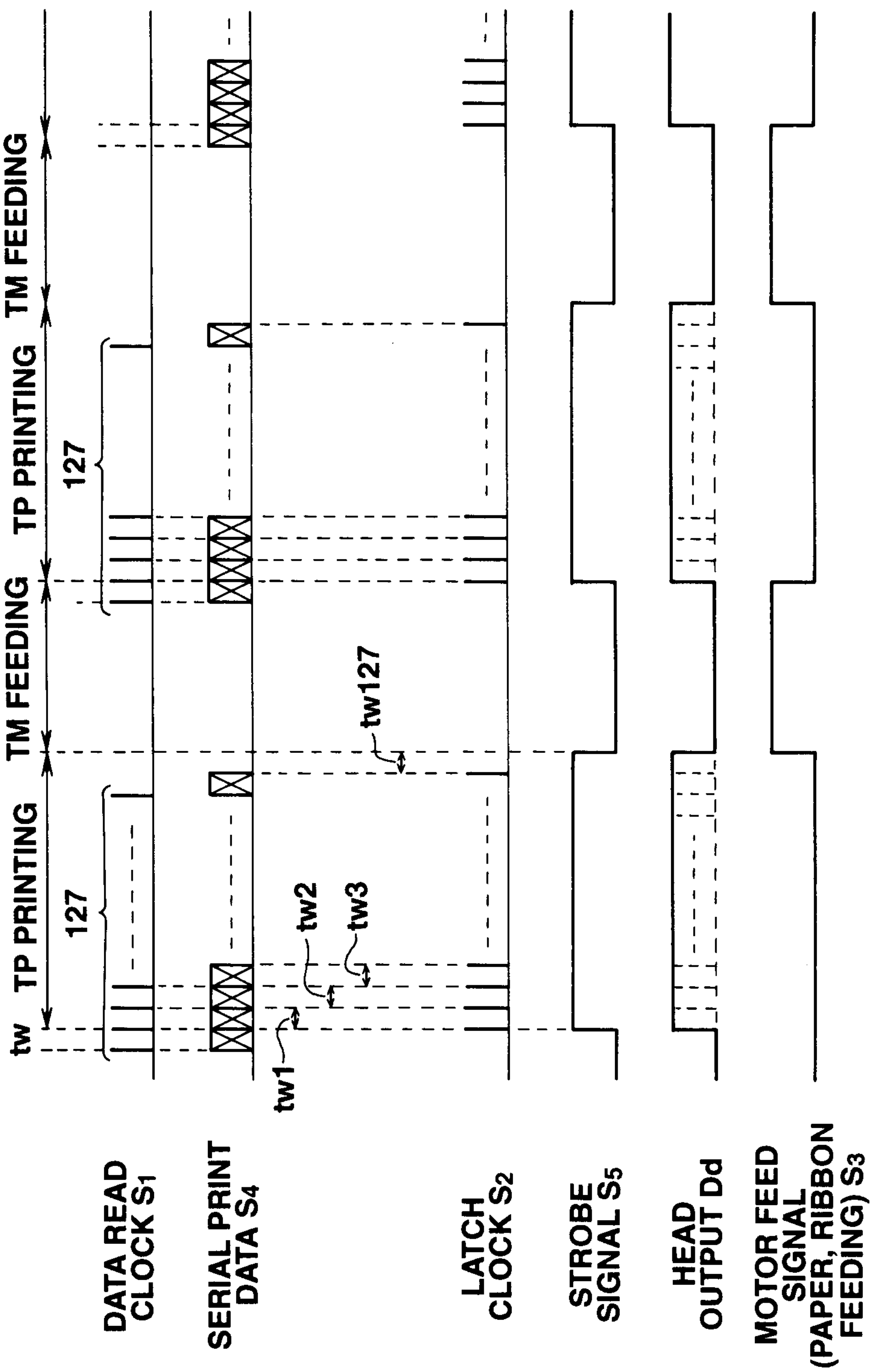


FIG.29A
FIG.29B
FIG.29C
FIG.29D
FIG.29E
FIG.29F
FIG.29G

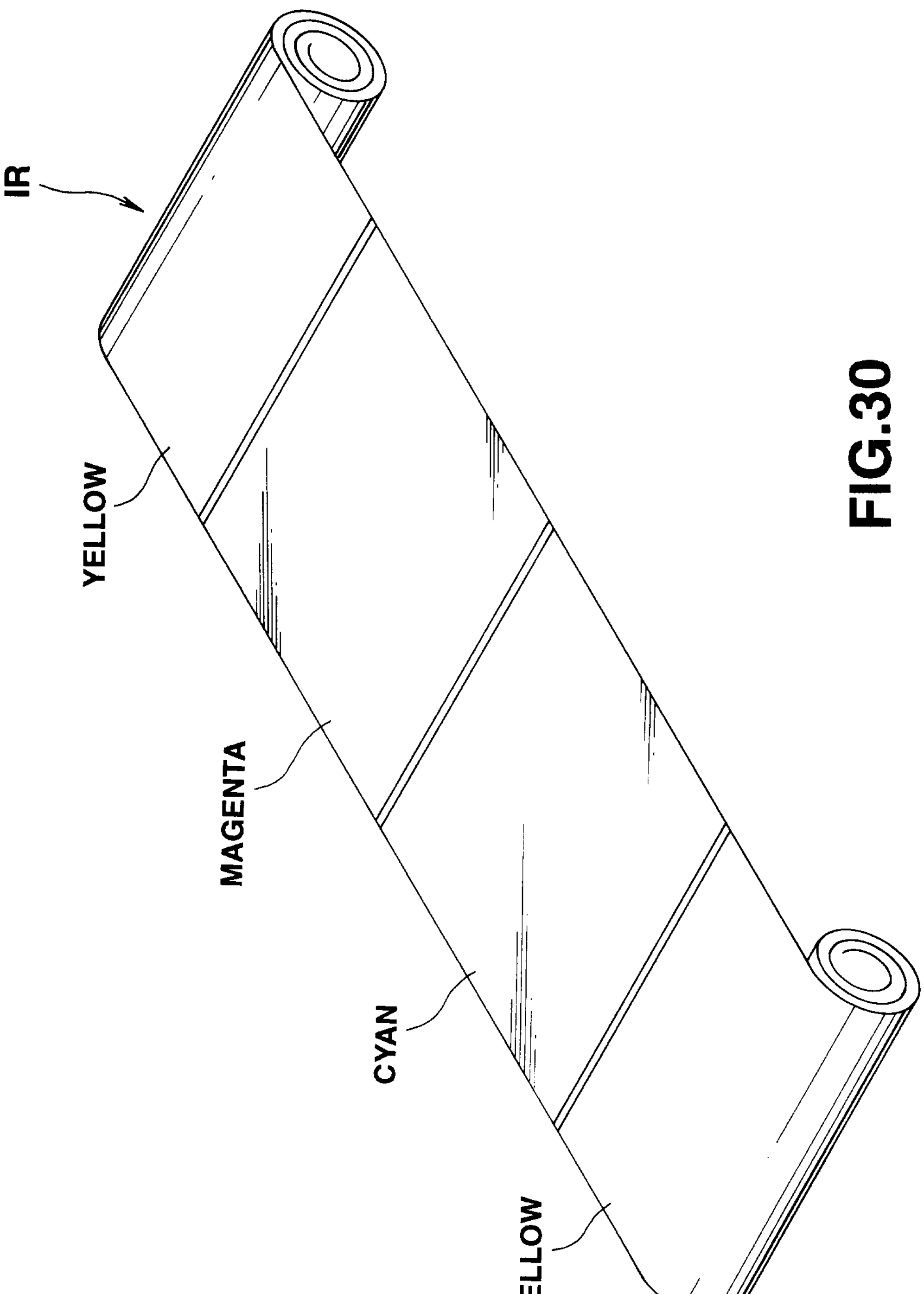


FIG.30

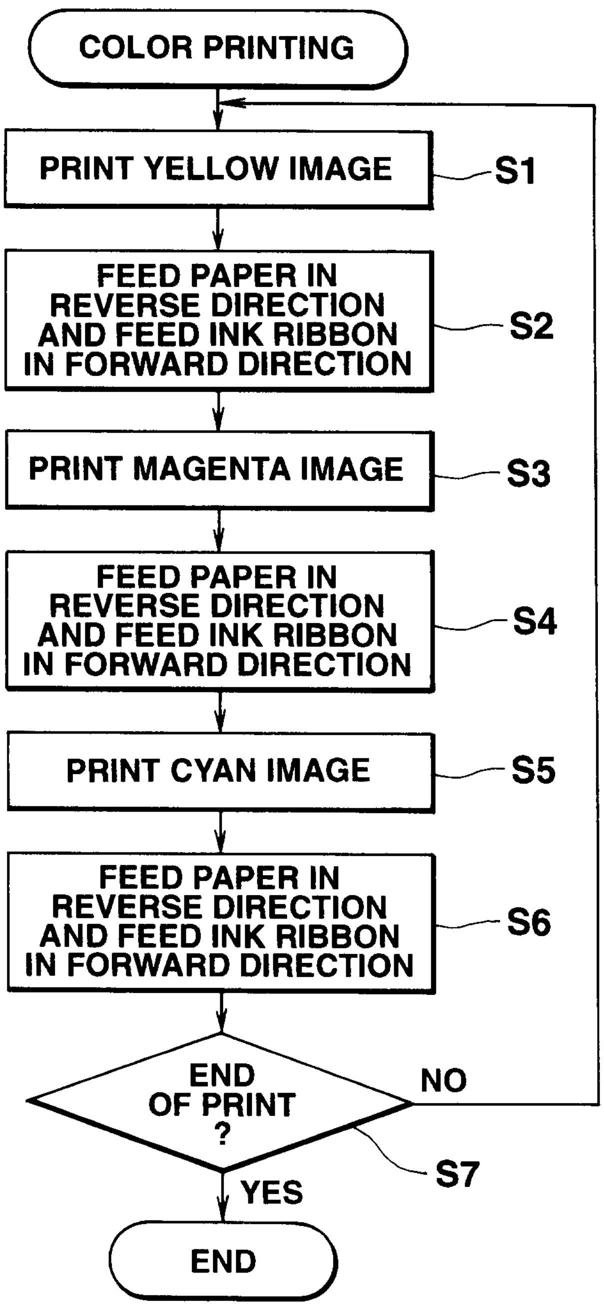

COLOR PRINTING
PRINT YELLOW IMAGE
S1
FEED PAPER IN REVERSE DIRECTION AND FEED INK RIBBON IN FORWARD DIRECTION
S2
PRINT MAGENTA IMAGE
S3
FEED PAPER IN REVERSE DIRECTION AND FEED INK RIBBON IN FORWARD DIRECTION
S4
PRINT CYAN IMAGE
S5
FEED PAPER IN REVERSE DIRECTION AND FEED INK RIBBON IN FORWARD DIRECTION
S6
END OF PRINT ?
NO
S7
YES
END

FIG.31